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The Impact of Domestic and Global Biofuel Mandates on the German Agricultural Sector

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October 2009

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1 Introduction

Biofuels are derived from biomass through a variety of technical processes. In the past decade they have received great attention and have become the focus of governmental and economic policies across the world. Subsidies for biofuels in the OECD are estimated to be around US$ 15 billion in 2007 (OECD/ITF, 2008).

Biomass is a general term that refers to living or recently dead biological material made from plants or animals. It includes wood, crops grown for energy purposes, agricultural and forestry residues as well as municipal solid wastes and industrial wastes[1]. Biomass constitutes the main supply of energy for the underdeveloped countries, wood and charcoal being the primary sources for heat and cooking (Barnes and Floor, 1996; Ezzati and Kammen, 2005). In the developed world biomass is slowly gaining greater importance as a source of renewable energy (OECD/IEA, 2008). Due to the variety of uses and products that stem from biomass, confusion may arise. Here the term biomass refers specifically to combustible renewables and wastes employed for electricity and heat production.

Biofuels, on the other hand, refer to bioethanol, biodiesel, biomethanol, biodymethylether and biooil. They are almost uniquely destined for the transport sector. Great expectations lie on their shoulders and several arguments have been advocated in their support. The quest for oil independence from a politically unstable region provides a strong motivation for institutional endorsement. Concerns over the future energy needs of China and India require alternative solutions to the current use of depletable resources. Furthermore, biofuels constitute a domestically produced renewable source of energy, they are labour intensive and they may solve the problem of declining farm income (Hahn, 2008).

However, biofuels are not an harmless alternative to our oil-craving society. Uncontrolled support may foster dangerous drawbacks associated with their production. At the present state of technology, they are derived from food feedstocks (sugar cane, corn and rapeseed above all) and a reallocation of these resources may have dramatic consequences on food prices and the poor (Mitchell, 2008). In addition, biofuels are a land intensive commodity potentially leading to soil erosion, deforestation, increased fertilizers and pesticides use as well as an alteration of natural landscape and biodiversity. Finally, their net contribution to a reduction in GHG emissions has been questioned as their production requires significant amounts of energy derived from fossil fuels (Pimentel and Patzek, 2005; Farrell 2006).

The strategic importance of biofuels and the complex interrelation between their manufacture, food supply and net GHG emissions contribute to the heated discussions sur-

[1] See US Department of Energy, Energy Efficiency and Renewable Energy at *http://www1.eere.energy.gov/biomass/biomass_basics_faqs.html*

rounding governmental support. External financial assistance remains a key element to guarantee the very existence and survival of a biofuel industry. Most biofuel programs across the world are operational only thanks to subsidies, tax exemptions or other forms of state aid (World Bank, 2008; Rajagopal and Zilberman, 2007).

The aim of this work is to evaluate the impact of domestic and global biofuel policies on Germany's agricultural sector. The central part of our study is divided into four sections. Section 2 presents in detail the issues that make biofuels a debated topic in today's economic policies. Fundamental aspects of our energy consumption patterns and the geographic location of our natural resources are highlighted together with a quantitative analysis of the recent surge in biofuels output capacity and estimates of their near-future deployment. An introduction to current and future biofuels production technologies is coupled with an overview of recent studies that assess their net contribution to harmful gaseous emissions and energy efficiency. The concerns associated with rising food prices and their likely causes are then briefly examined.

Section 3 provides a thorough description of the subsidy, taxation and protection measures granted to biofuels across the world. Current governmental policies in the EU and its member states are given special attention. Section 4 presents the current literature on economic modelling and focuses on partial equilibrium (AGLINK-COSIMO, Impact, Esim, etc.) and general equilibrium frameworks (EPPA, GTAP, etc.).

Section 5 simulates the impact of domestic and global biofuel policies in Germany within a Computable General Equilibrium framework. The LEITAP model is introduced. A description of the analysed scenarios is given on the basis of the envisaged biofuel blending mandates described in section 3. The simulation results are then evaluated with respect to production, prices, international trade and land use of the relevant commodities. The outcome clearly indicates that current biofuels policies significantly affect food markets as well as land allocation.

The conclusion summarizes the main findings of our study and draws a comparison with results of other publications. The model's limitations and suggestions for future research are highlighted. Two appendixes are also included at the end of the study. Appendix A provides the conversion ratios of ethanol production from switchgrass according to second generation techniques. Appendix B describes in more detail the estimation of the biofuel shares associated to the regional aggregation of the LEITAP model.

2 The World Outlook

According to the International Energy Agency (IEA) in 2005 the total primary energy supply of the world amounted to 11433.92 Mtoe[2,3]. Around 80% of it was derived from fossil fuels: coal, oil[4] and gas. Fossil fuels are exhaustible natural resources situated in a small number of countries. As the world's energy needs will be 50% higher in 2030 compared to today[5], how fossil fuels are managed, allocated and priced is of crucial importance.

The Middle East and North African region are exceptionally well endowed with such precious assets: they claim the rights to 61% of the world's proven oil reserves and 45% of gas resources. Yet their share of global production is below par. In 2004 it totalled only 35% for oil and 15% for gas (IEA, 2005). This scenario contributes to a rather tense geopolitical outlook (Ross, 2008).

Russia is the largest exporter of natural gas, the second biggest exporter of crude oil after Saudi Arabia and the first exporter of petroleum products. It trails only Australia and Indonesia as exporter of hard coal and enjoy a high installed capacity of nuclear electricity relative to its current electricity needs. Overall, Russia is the largest net exporter of energy in the world (Table 1).

The United States, on the other hand, are by far the largest net importers. It is no wonder that they are highly concerned with energy independence. They are the strongest economy on the planet, have a substantially larger energy production than any other country and cause the greatest amount of CO2 emissions at the aggregate level.

The development of China and India as well as the continued prosperity of developed nations are dependent on the future availability of energy resources. In this context technological advances play an extremely important role. There is an increasing effort to find alternative solutions to the current sources of power, coupled by attempts to reduce CO2 emissions. New discoveries should increase the efficiency and reduce the costs of renewable energy sources such as solar, wind, hydro, tidal, geothermal or biomass.

Liquid fuels supply the largest share of the world's energy consumption[6] and they are expected to continue their relative dominance of the energy markets due to substantial increments in the demand from the transport sector. In addition, liquid fuels are almost

[2] "Key World Energy Statistics 2007," The International Energy Agency, p. 37.

[3] Mtoe: Million tonnes of oil equivalent

[4] When crude oil and petroleum derivates are combined.

[5] "International Energy Outlook 2008," Energy Information Administration, p. 1 of highlights.

[6] *International Energy Outlook 2008,* Energy Information Administration, excerpt from the "Highlights".The liquid fuels category includes petroleum derived fuels and non-petroleum derived fuels such as ethanol, biodiesel, coal-to-liquids, gas-to-liquids, petroleum coke, natural gas liquids, crude oil consumed as fuel and liquid hydrogen.

Region/ Country	**Energy Prod.**	**Net Energy Imports**	**TPES**	**CO2 Emis.**	**CO2/ Popul.**
	Mtoe	Mtoe	Mtoe	Mtonnes of CO2	CO2 ton. per capita
World	11468		11434	27136	4.22
OECD	3834	1813	5548	12910	11.02
Mid. East	1496	-979	503	1238	6.62
Ex USSR	1551	-565	980	2303	8.08
Asia	1114	199	1286	2591	1.25
Lat. Amer.	680	-168	500	938	2.09
Africa	1088	-475	605	835	0.93
Brazil	188	25	210	329	1.77
Canada	401	-134	272	549	17.00
China	1641	100	1717	5060	3.88
France	137	143	276	388	6.19
Germany	135	214	345	813	9.87
India	419	122	537	1147	1.05
Iran	304	-141	163	407	5.96
Italy	27	159	185	454	7.76
Japan	100	439	530	1214	9.50
Mexico	259	-81	177	389	3.70
Russia	1185	-531	647	1544	10.79
S. Arabia	577	-434	140	320	13.83
U.A.E.	168	-111	47	110	24.37
U.K.	204	32	234	530	8.80
USA	1631	735	2340	5817	19.61

Source: *Key World Energy Statistics*, International Energy Agency, (2007)

Table 1: Key Energy Statistics, 2005 Data

exclusively derived from oil, which plays the lion's share in our energy needs accounting for 35% of our total demand in 2005.

The Middle East detains the overwhelming majority of proven oil reserves (Table 2). Even though Russia is the second producer with 9.04 million barrels a day in 2005, its reserves rank 8^{th} in the world and its estimated reserves-to-production ratio spans only 18 years. Saudia Arabia produces little more oil with its 9.55 daily million barrels, but it boasts a 75 years reserves-to-production ratio. While the reserves-to- production relationship generally follows a linear extraction rule, there are substantial differences in the extraction-to-reserves quotient between non-OPEC member and OPEC countries (Pickering, 2008)[7].

[7]The extraction to reserves quotient is based upon peak oil production and its importance is often overlooked from an economic perspective (Holland, 2008).

Country	Oil Reserves	Country	Production in 2005	Share World Prod.	Reserves to Prod.
	Billion Barrels		Million Barrels per day	%	Years
S.Arabia	263.3	S.Arabia	9.6	13.4	75
Canada	179.2	Russia	9.0	12.6	18
Iran	136.3	USA	5.2	7.2	11
Iraq	115	Iran	4.1	5.7	83
Kuwait	101.5	China	3.6	5.0	1
UAE	97.8	Mexico	3.3	4.6	12
Venezuela	80	Norway	2.7	3.7	9
Russia	60	Nigeria	2.6	3.6	37
Libya	41.5	UAE	2.5	3.5	106
Nigeria	36.2	Kuwait	2.5	3.5	110
Kazakhstan	30	Venezuela	2	2.7	107
USA	21.8	Iraq	1.9	2.6	168
China	16	Algeria	1.8	2.5	18
Qatar	15.2	UK	1.7	2.3	7
Mexico	12.4	Brazil	1.6	2.3	18
Algeria	12.3	Libya	1.6	2.3	65
Brazil	11.8	Canada	1.3	1.8	10
Angola	8	Angola	1.3	1.7	12
Norway	7.8	Indonesia	1.1	1.5	12
Azerbaijan	7	Kazakhstan	1.1	1.5	23
R.o.W.	65.5	Qatar	0.8	1.2	50
World Tot.	1371.4	Oman	0.8	1.1	19

Source: *Key World Energy Statistics*, International Energy Agency, (2007)

Table 2: World Oil Reserves and Production, 2005 Data

The perceived refusal of the OPEC cartel to increase production at a time of rising oil prices caused political tension and incentivized the use of alternative solutions. Higher oil prices make alternative products relatively cheaper and indirectly benefit the diffusion of biofuels. The majority of policies promoting the use of biofuels were drafted between 2003-2008, a period of sharp increases in the price of oil. In May 2008 the cost of crude oil exceeded US$130 per barrel, breaking the inflation adjusted record set in the early 1980s and leading to a 2.5 fold increase from 2004, when oil peaked at US$50 a barrel (Brook *et al.*, 2004; Krichene, 2008).

While the rise in petroleum prices is considered inevitable in the long term, it is nonetheless difficult to make accurate predictions about its future course. The staggering increment in the cost of crude oil was followed by a global financial crisis that hit the world in the second half of 2008 and reverted the oil trends of the previous few years. The crisis was triggered by a real estate bubble and the devaluation of mortgage backed securities in the United State. The financial turmoil was worsened by the unprecedented decline of major investment banks and the consequent endemic demolition of investors' confidence across the globe (Calomiris, 2008). However, the oil price peaks have likely contributed to undermine the economy.

There is a large body of literature covering the impact of oil shocks on a country's financial system. As Hamiltonne (2005) points out, "nine out of ten of the US recessions since World War II were preceded by a spike up in oil prices[8]." Given that oil satisfies more then a third of our global energy needs and that it has a low short term elasticity of substitution in key sectors such as transport, it is no wonder that the economic impacts of oil pikes are far fetched. Rogoff (2006) asserts that today "oil price fluctuations impact global economic growth somewhat less than they did two or three decades ago[9]." Nonetheless, the timing of the recent financial turmoil suggests that the oil price surge may have been an overlooked factor that weakened the economy and aggravated the crisis.

Several causes have been ascribed to the latest oil price surge. Increased demand from India and China certainly has been important. Krichene (2008) also highlights how low interest rates and a fast depreciating US dollar put upward pressure on prices, coupled by market speculation that anticipated further rises. Dées *et al.* (2008) identify a lack of spare refining capacity and a non-linear relationship between prices and supply.

Regardless of the causes that prompted such escalation, the latter has once again highlighted our dependency on imported resources and called for an increase in investments into alternative solutions. Energy security has been a key issue in President G. W. Bush's political agenda[10]. EU policies have also gone in a similar direction[11]. Biofuels have been at the very centre of attention. They are meant to reduce the impact of petroleum on the world economy, contribute to greater energy security and reduce pollution. These are the recurrent arguments employed to justify the policy packages adopted. In addition, they can increase income for farmers and help the development of rural areas (Hahn, 2008). Even though expensive oil makes biofuels relatively cheaper, their development requires direct governmental assistance. At the current level of technology biofuels production costs are too high and their supply feeds on state subsidies (Rajagopal and Zilberman, 2007). Only Brazil has a fully integrated biofuels market, whereas in the rest of the world

[8]Hamiltonne (2005), p.1

[9]Rogoff (2006), p. 2

[10]Twenty in Ten: Strengthening America's Energy Security, available at *http://www.wihitehouse.gov/stateoftheunion/2007/initiatzives_/energy.html.*

[11]See for instance: Proposal for a Directive of the European Parliament and of the Council on the Promotion of the Use of Energy from Renewable Sources [COM(2008) 30 final], 23.1.2008; or Communication From the Commission "Biomass Action Plan." SEC(2005) 1573, Brussel 7.12.2005.

World Ethanol Production in Billion Liters		World Biodiesel Production in Billion Liters	
Country	**2007**	**Country**	**2007**
USA	24.6	EU	6.1
Brazil	19.0	USA	1.7
EU	2.2	Indonesia	0.4
China	1.8	Malaysia	0.3
Canada	0.8	Brazil	0.2
Thailand	0.3	China	0.1
Colombia	0.3	Canada	0.1
R.o.W.	0.6	R.o.W.	1.3
World Tot	49.6	World Tot	10.2
Source: RFA Industry Stat., F.O. Licht		Source: FAO (2008), F.O. Licht	

Table 3: World Fuel Ethanol and Biodiesel Production

the attractiveness of biodiesel or bioethanol relies heavily on external subsidies and the potential for technological breakthroughs.

2.1 Biofuels Output

Currently fuel ethanol output largely surpasses the amount of biodiesel produced across the world. In 2007 almost fifty billion litres of ethanol were manufactured while biodiesel supply reached ten billion litres. The United States and Brazil are the leading producers of ethanol and together account for almost 90% of the total. Despite similarities in the quantity of ethanol manufactured, the two countries present substantial differences in their production and cost structure.

The United States are the largest manufacturer of ethanol in the world (Table 3). The RFA[12] (2008) measures total US output at 24.6 billion litres in 2007[13]. Production is highly subsidized and almost uniquely based on corn. Schnepf (2005) estimates that around 90% US ethanol is obtained from maize. However, the latter is not a cost competitive feedstock at the current technology level and extensive subsidies are provided by the government to support national biofuels production. According to the EIA (2007), the financial incentives were such that 20% of the available US corn supply was devoted to ethanol manufacture in 2006. The government is currently trying to develop second-generation technologies that would provide an alternative to food feedstocks, though it is not decreasing its subsidies to support corn-based production.

[12] Renewable Fuels Association, RFA, *2007 World Fuel Ethanol Production*, citing as source F.O. Licht, (2008). Available at *https://www.ethanolrfa.org/industry/statistics/#E.*

[13] Original RFA data are in gallons. See the appendix for the conversion table adopted.

European Ethanol Production in Million Liters			**European Biodiesel Production** in Million Liters		
Country	**2007**	**2006**	**Country**	**2007**	**2006**
France	539	293	Germany	3.284	3.025
Germany	394	431	France	991	844
Spain	348	296	Italy	413	508
Poland	155	161	Austria	303	140
Sweden	70	140	Portugal	199	103
Italy	60	78	Spain	191	113
Czech Rep.	33	15	Belgium	189	28
Slovakia	30	0	UK	170	218
Hungary	30	34	Greece	114	48
Netherlands	14	15	Netherlands	97	20
Lithuania	20	18	Denmark	97	91
UK	20	0	Poland	91	132
Latvia	18	12	Sweden	72	15
Finland	0	0	Rest EU	283	272
Total	**1.731**	**1.593**	**Total**	**6.492**	**5.557**
Source: European Bioethanol Fuel Association (eBio)			Source: European Biodiesel Board (orig. data in tonnes)		

Table 4: European Biodiesel and Ethanol Production in 2007 and 2006

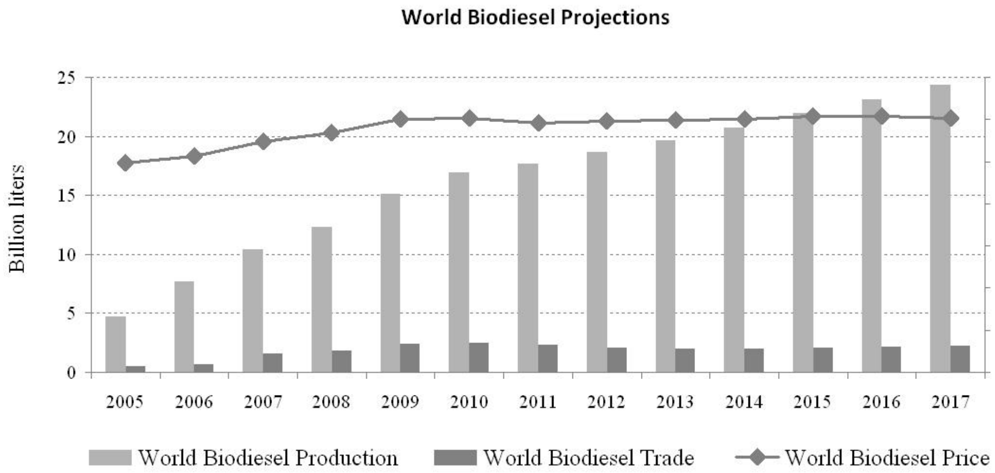
Brazil's ethanol output closely trails that of the US at 19 billion litres in 2007. However, its production feeds on sugar-cane and is cost competitive. Currently the Brazilian government does not offer direct subsidies to ethanol production (de Almeida *et al.*, 2008), though this result comes after a long history of support that dates back to the 1970s.

The EU and China contribute to a much lower share of ethanol supply with 2.1 billion liters and 1.8 billion liters respectively. On the other hand, the EU is the world's leader in the biodiesel market with an output of 6.1 billion litres.

Within the EU, Germany is the largest biodiesel producer on the globe. Its main feedstock is rapeseed. According to Kutas *et al.* (2007), Germany has 30 biodiesel plants and plans to construct 9 further factories, thus extending its production capacity to 4.8 billion litres by the end of 2010[14]. However, following recent reductions in government support a decline in biodiesel output may occur in the immediate short term[15].

[14]Kutas *et al.* (2007), p. 10. Data is given in tonnes. See appendix for conversion rates.

[15]See article by Michael Hogan, Reuters, 15.01.2008, Available at *http://www.reuters.com/articlePrint?articleId=USL1589672020080115.*



Source: OECD/FAO (2008)

Figure 1: World Biodiesel Projections

In 2006 France had the second largest installed production capacity of biodiesel (15% of the EU total versus 54% for Germany) and the second highest level of consumption (14% of the EU total versus 63% for Germany)[16]. It is also the first ethanol manufacturer of the EU (based on sugarbeet) and has been investing in the expansion of its output facilities. Biodiesel capacity is expected to reach 3.8 billion liters by 2010 thanks to the development of 15 new sites, while ethanol's potential supply should rise to around 1.9 billion liters by 2010 (Kutas *et al.*, 2006)[17].

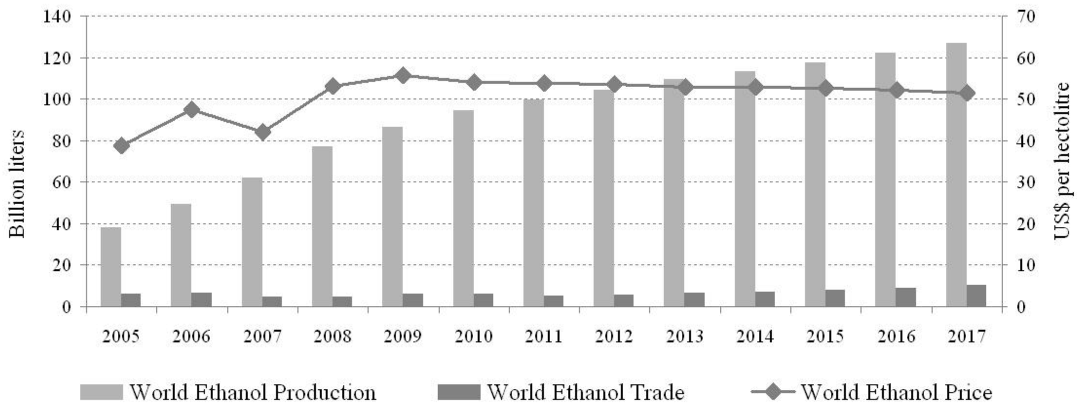
Production costs vary depending on the specific inputs used (i.e. corn, sugar cane, sugarbeet etc.) and their relative processing expenses. Generally the feedstock constitutes the most expensive component of the mix. In the case of ethanol produced from wheat and maize, crops constitute more than 75% of the total manufacturing expenses (FAO, 2008). Even though at the current state of technology costs exceed profits and production occurs mainly thanks to governmental help, capacity expansion is underway on a large scale in the whole world.

According to the OECD/FAO (2008), in 2017 world biodiesel production is expected to more than double its 2007 level and surpass the 24 billion liters mark (Figure 1). A similar performance is projected for the global supply of ethanol with a total output of almost 127 billion liters by 2017 (Figure 2). Average world prices are forecasted to reach a relatively stable level around US$105 and US$50 for biodiesel and ethanol respectively. Trade in biofuels is limited and maintains a rather constant level over the years. This indicates that production is mostly destined for national consumption.

[16] Kutas *et al.* (2006).

[17] Original data in tonnes, see appendix for conversion rates

World Ethanol Projections



Source: OECD/FAO (2008)

Figure 2: World Ethanol Projections

2.2 Biofuels Production Techniques and Their Assessment

Biofuel can be divided into *first generation* and *second generation*. The distinction between the two groups is based upon the type of feedstock employed in their respective production. First generation biofuels are made from food crops. Alternative fuels of the second generation are manufactured from non-edible feedstock.

First generation biofuels are produced from grains, sugars or oil seeds. Grains and sugar are employed in the manufacture of ethanol. Oil seeds, on the other hand, are destined for biodiesel. Grains such as corn or maize are rich in starch. Starch is converted into sugar with the help of enzymes in a process called saccharification[18]. The sugar is then fermented to produce ethanol or butanol, depending on the fermentation organisms employed[19]. Sugar plants such as sugar cane and sugar beet are processed to obtain sugar juice and molasses, which are fermented into ethanol (Royal Society, 2008).

First generation biodiesel is derived from the oily seeds of sunflower, rapeseed, soybeans, coconut, palm and jathropa (recycled cooking oil and animal fats can also be used). Biodiesel in the form of fatty-acid-methyl-ester (FAME) is obtained from vegetable oils through transesterification[20] by an alcohol, usually methanol. In some countries (e.g. Malaysia) plant oil is used directly as substitute for the standard diesel fuel[21].

[18]Saccharification is the hydrolisis of cellulose into glucose (sugar).

[19]See for instance *How Ethanol is Made* by the Renewable Fuel Association at *http://www.ethanolrfa.org/resource/made/*.

[20]Transesterification is the process of exchanging the alcohol group of an ester compound with another alcohol.

[21]See for instance Celeste Peltier's *Making Biodiesel* for a more detailed account on how to make biodiesel at *http://www.humboldt.edu/~ccat/biodiesel/makingbiodiesel/celesteSP2001/makebiod.pdf*.

The feedstock of choice for biofuel manufacture depends on the climatic and geographic characteristic of the producing country. Brazilian ethanol is derived from sugar cane, whereas the United States use almost uniquely corn. Malaysia and Thailand contribute to around 80% of world's palm oil production and employ the latter as biodiesel feedstock, while Germany makes biodiesel from rapeseed.

The inputs used in the production of biofuels have important implications for the manufacturing costs, energy conversion efficiency and overall environmental impact. Several studies have been published to evaluate alternative feedstocks and technical processes. Micro-economic valuation of manufacture costs, land-use efficiency, lifecycle assessment (LCA) of net energy balance and of net Greenhouse Gases emissions are the criteria adopted[22].

The most expensive component of first generation biofuels production is the crop feedstock (Ag-Link Cosimo Database, OECD-FAO, 2008). With the exception of Brazilian ethanol producers, the high cost of the feedstock renders production of biofuels unprofitable unless oil prices per barrel are above the US$50-70 range (Larson, 2008), thus requiring governmental support in order to sustain the biofuel industries.

Land-use efficiency is an element of crucial importance in the assessment of bioethanol and biodiesel manufacture. As Larson (2008) reports, starch based first generation biofuels are the least land-efficient, where land-use efficiency is measured in km/year of vehicle travel achieved via the biofuel output from one hectare. Sugar-based first generation technologies are on average twice as land-efficient. Rajagopal (2007) and Rajagopal and Zilberman (2008) provide detailed values for land and water intensity of major crops for ethanol and biodiesel production. In their measure of gasoline equivalent ethanol yield (liter/hectare) the rankings or land-efficiency roughly correspond to those of Larson (2008). Goldember and Guardabassi (2009) present current land use and discuss the implication of future biofuel expansion in relation to recent criticism moved by Fargione *et al.* (2008) and Searchinger *et al.* (2008).

Life Cycle Assessment (LCA) of the net energy balance and of the net GHG emissions have been estimated by various authors. Two main life cycle stages have been identified: the agricultural phase (when crops are grown) and the transformation of the energy crops into fuels. Accurate analyses also consider the energy and GHG balance debt caused by the transport of the feedstock to the conversion facilities. LCA models usually focus on specific biofuel types, the geographical region of production and cultivation as well as the conversion technologies adopted. Whereas this procedure is necessary to calculate correct estimates, it renders comparisons across studies relatively difficult. In addition,

[22] Besides net energy and GHG emissions, there are LCA studies analyzing environmental concerns such as water pollution, air quality, biodiversity and soil quality preservation. However, only a limited number of studies has been conducted with respect to the non-GHG environmental issues and they will not be discussed here as there is a more limited consensus to their actual results.

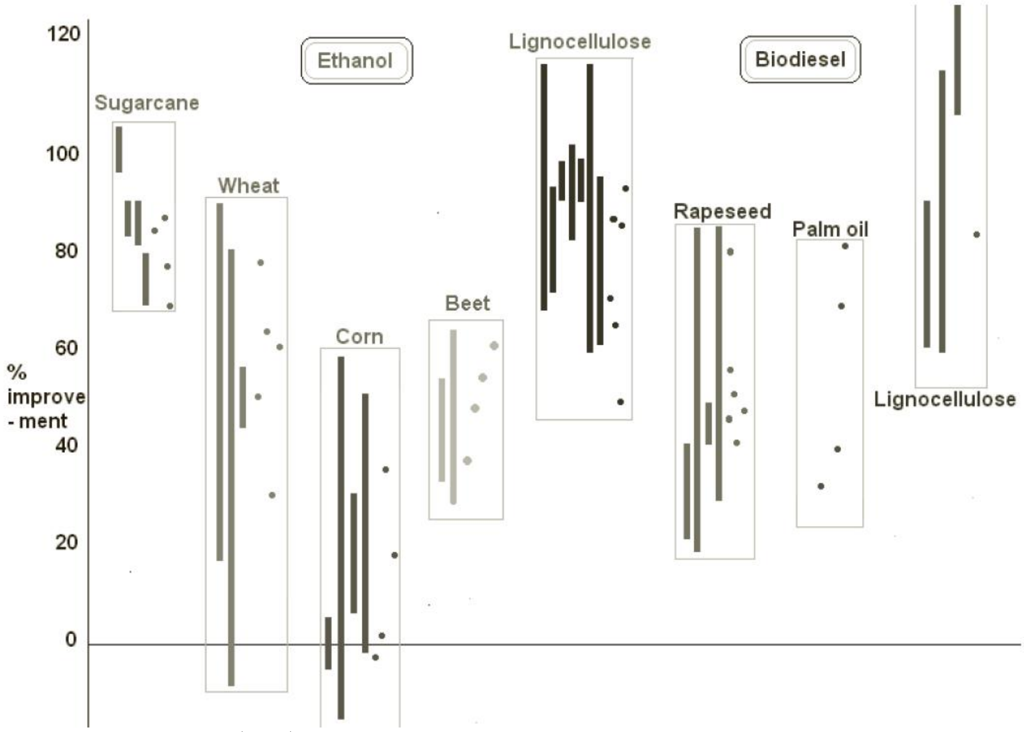
key parameters may vary across LCA valuations. In particular there might be great variations with respect to how nitrous oxide (N2O) is incorporated in the calculations. The employment of fertilizers during the agricultural phase causes emissions of N2O, which was blamed by Crutzen *et al.* (2007) for preventing a reduction in global warming through increased biofuels use.

Pimentel and Patzek (2005) argue that ethanol production using corn, switchgrass or wood as well as biodiesel production using soybean and sunflower cause net losses in terms of both energy and GHG emissions. Farrell *et al.* (2006) evaluate six different studies of ethanol production from corn and conclude that there is a net energy gain and a very low gain in GHG emissions. In addition, Farrel *et al.* (2006) claim that previous studies have ignored in their analyses the importance of co-products and may have used obsolete data. Macedo *et al.* (2004) assess the use of sugar cane for ethanol production in Brazil and state that there are net energy and net GHG emissions reductions. Janulis (2004) also estimates a positive contribution toward a decrease in energy use and carbon dioxide release from the production of biodiesel from rapeseed oil in the EU.

The above mentioned publications are however only a limited selection of a vast and often contradictory literature that has not reached a general consensus. It is perhaps more useful to refer to a review of over 60 different studies that has been conducted by the OECD (2008)(See Figure 3). The latter gives an indicative range of comparable results across biofuel types subdivided by feedstock. The review concludes that ethanol production from sugarcane obtained the most consistent results across different studies and shows the greatest GHG improvement. Ethanol produced from corn is the most ineffective in reducing harmful gaseous emissions.

Second generation biofuels (i.e. fuels derived from non-edible feedstock) are meant to diminish the impact of our energy needs on food supplies, lead to higher production per unit of land area, increase land efficiency, lower feedstock costs and induce energy and environmental benefits in comparison to their first generation counterparts. However, they require more complex manufacturing procedures and costly equipment leading to greater capital investments in per unit of output and the need for larger facilities to enjoy the benefits of scale economies. Above all, they remain a promise to be fulfilled. Today there are no commercially viable production sites of second generation biofuels (Larson, 2008).

Second generation biofuels are derived from ligno-cellulosic biomass. Lignocellulosic sources generally are woody crops or energy grasses such as switchgrass and miscanthus. The latter are fast growing grasses that are not used for food or fiber production. The composition of lignocellulosic biomass varies across plants, but on average it is made of 40% cellulose, 30% hemicellulose, 20% lignin and a remaining 10% of other compounds (Lee *et al.*, 2007).



Source: OECD (2008)

Figure 3: Life Cycle of GHG Emission Improvement of Selected Biofuel Pathways as Compared to Gasoline and Diesel Fuels (Without Land Use Change)

The procedures employed to manufacture second generation biofuels can be grouped into two categories: biochemical and thermochemical biomass conversion. Biochemical processes are employed to manufacture ethanol or butanol. Hamelinck and Faaij (2006) describe how the lignocellulosic biomass is pre-treated to separate cellulose, hemicellulose and lignin. Lignin is then removed, as it cannot be fermented into ethanol, but it can be used as a byproduct to contribute for heat and electricity production. The cellulose is hydrolized to glucose and the hemicellulose is hydrolysed to sugars, which are then fermented.

Thermochemical processes give rise to fuel substitutes for both gasoline and diesel. Gasoline substitutes are methanol or Fischer-Tropsch (FT) gasoline, while Fischer-Tropsch (FT) diesel and dimenthyl ester (DME) are alternatives to petroleum-based diesel. In addition to being more flexible in the choice of fuel output and feedstock used, thermochemical conversion requires considerably higher temperatures and pressure levels in comparison to biochemical technologies. Gasification or pyrolysis are the first steps of the thermochemical process. Gasification is more capital-intensive and needs greater production facilities to enjoy the benefits of economies of scale (Larson, 2008). During gasification biomass is heated and transformed into combustible and non-combustible gases. The gas is cleaned of contaminants and syngas is produced, which is a mixture of carbon monoxide (CO) and hydrogen (H2). The syngas undergoes a series of chemical reactions when passed through a catalyst, where the CO and the H2 react to produce liquid fuels (FT gasoline or diesel) or DME[23] (Hamelinck and Faaij, 2006).

Even though second generation biofuels are meant to reduce the cost of feedstock, improve environmental concerns and, above all, limit the competition for land and crops with food production, they remain a welcome but not yet commercially viable option. A more complete overview of the biofuel production techniques is given in Figure 4.

2.3 Food and Biofuels

Food commodities experienced a decline in real prices until very recently. Between 1971 and 2000 the price of food dropped in real terms by almost 60%, whereas the cost of agricultural goods followed a similar trend and fell in real terms by about 55% (Schmidhuber, 2007).

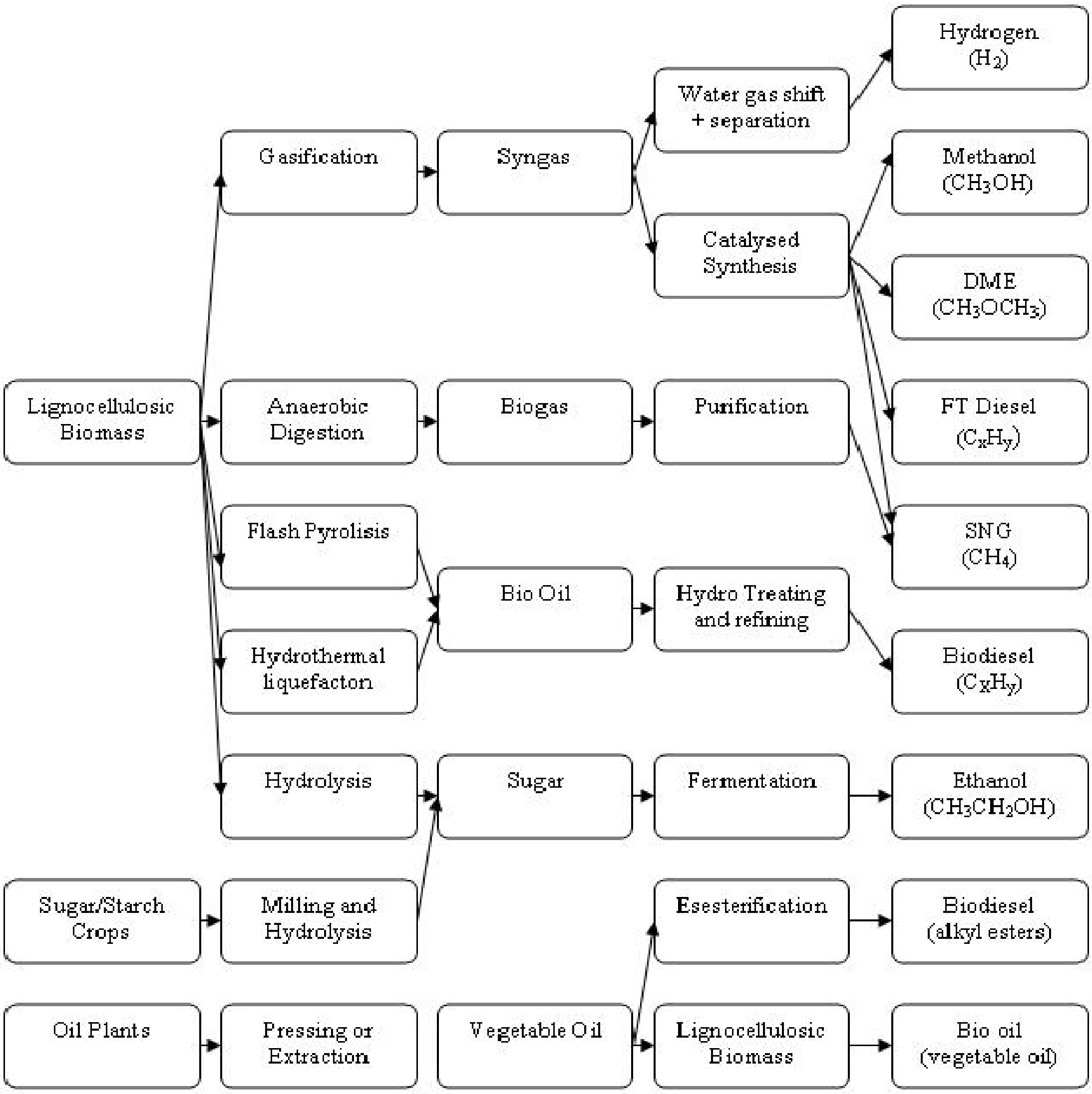
In the last few years this trend was dramatically reversed triggering talks of a food crisis and depletion of stocks[24]. From early 2007 to mid 2008 wheat prices have increased by over 40%, rice prices jumped by more than 60% and soybean prices also rose by 40% (UNCTAD, 2008). Fats and oil prices have experienced a staggering increment. Palm oil went up 200% between January 2005 and June 2008, soybean oil followed with an increase of 192% over the same period. The IMF's index of internationally traded food commodities prices rose 130% between January 2002 and June 2008 and 56% between January 2007 and June 2008 (Mitchell, 2008).

It has been argued that the recent surge in prices has been caused, or at least partially driven by, increased biofuel production (Johnson, 2007; Mercer-Blackman *et al.*, 2007). Biofuels are manufactured mainly from maize, palm oil and oily seeds as well as sugar cane and sugar beet. The consequent higher demand for these commodities coupled with a reallocation of land that diverted resources from other food products has been indicated as a relevant factor in the current rise in food prices.

Mitchell (2008), D. O. Lead Economist of the Development Prospects Group at the World Bank, has argued that biofuels are a major driver of food prices, particularly for maize. The US contribute to around one third of global maize production and two

[23] Dimethyl Ester (DME) is a gas that liquifies under low pressures. Its physical properties make it a potential substitute for Liquified Petroleum Gas (LPG, a mix of butane and propane). It can also be used as a fuel for diesel engines due to its high cetane number. However, DME cannot be blended with conventional diesel for current engines (Larson, 2008).

[24] See for instance articles such as "Food Crisis - Soaring Prices Are Causing Hunger Around the World" published on the *Washington Post* on the 14.03.2008 available at *http://www.washingtonpost.com/wp-dyn/content/article/2008/03/13/AR2008031303347.html* and "After the Oil Crisis, a Food Crisis?" published on *Time* on the 16.11.07 and available at *http://www.time.com/time/business/article/0,8599,1684910,00.html.*



Source: Hamelinck and Faaij (2006)

Figure 4: Overview of Conversion Routes from Crops to Biofuels

thirds of the world's exports. The US are also the largest producer of fuel ethanol and employ predominantly maize in its production, using up to 25% of total domestic maize production in 2007-2008.

With respect to vegetable oil Mitchell (2008) claims that one third of the increase in global consumption between 2004 and 2007 was due to biodiesel production, which absorbed around 7% of the world's supply in 2007.

In addition, he suggests that land use changes caused by higher biofuel feedstock production have been substantial and brought to a reduction in the production of other crops. He argues that in the US in 2007 the 23% increase in the area cultivated with maize led to a 16% decrease in the surface dedicated to soybean production. He further states that the 8 largest wheat exporting countries experienced an expansion in rapeseed and sunflower by 36% while the surface devote to wheat cultivations fell by 1% between 2001 and 2007.

The UNCTAD pespective on the matter reduces the blame on biofuels. In an official document entitled *UNCTAD's Position on Biofuel Policies and The Global Food Crisis*[25] they assert:

> It is UNCTAD's view that increased biofuel production has been, for certain crops and certain countries, a driver of food price inflation, but not the dominant one. Long-term factors - such as the failure of giving the agricultural sector the importance it deserved during the last decades, lack of investments in productive capacity and infrastructure, distorted agricultural markets and the dismantling of support policies for domestic markets - seem to be by far more accountable for the present food crisis than biofuels.

The UNCTAD argues that the price of wheat, rice and sugar can have been influenced by biofuel policies only mildly. Wheat is indeed a minor feedstock of biofuel manufacturing. Only 0.6% of wheat is employed in biofuel production globally. While land-use changes may have occurred (though Mitchell (2008) estimated only a 1% change in wheat cultivated surface between 2001 and 2007), unfavourable weather conditions in Australia and Ukraine may have played a greater role. Rice prices doubled between 2007 and 2008, but rice is not used in biofuel manufacture. The UNCTAD suggests that export restrictions by major producing countries coupled with surging demand by nations that aimed at reconstituting rice reserves or at compensating losses due to floods have been a key factor in the evolution of the latter's price. Sugar prices have also been increasing. Sugar is a major feedstock in biofuel production, but for two consecutive years supplies have exceeded demand. High energy prices, the weakness of the dollar and speculation on

[25]UNCTAD, United Nations Conference on Trade and Development, *UNCTAD's Position on Biofuel Policies and the Global Food Crisis*, available on the 07.04.2009 at *http://www.unctad.org/Templates/Page.asp?intItemID=4526&lang=1*

sugar futures markets have been ascribed as potential explanatory factors of the discrepancy between sugar prices and market fundamentals. Sugar production estimates still maintain that production will exceed consumption.

Collins (2008) presents an analysis of the current situation in the US and cites several elements that contributed to the price increment of farm products, but devotes special attention to biofuels. The UNCTAD (2008) however claims that from a global perspective the food crisis can be reconducted to the simultaneous interplay of variety of causes. The recent rise in food prices was not due to energy costs, climatic conditions, speculation or biofuel production alone. Structural long-tem issues affecting the global supply have played an important role. Relatively low or decreasing agricultural productivity in developing countries is noted as a fundamental factor. The lack of public and private investments in the rural and agricultural commodities in less developed nations, despite the relative importance of agriculture in their economies, has highlighted a dangerous failure in their development strategy and constituted a constraint in the evolution of supply. Issues concerning oligopolistic market structures (especially among food-retailers) and protectionist policies have contributed the surge in food prices between 2001 and 2008.

Nonetheless, the relationship between food and biofuels remains crucial and increasingly important. Von Braun (2007) notes that high economic growth, population change and stock developments as well as the evolution of the corporate food system have reshaped the supply and demand framework of the food equation. Importantly, he points out that energy prices are becoming increasingly linked to the commodities employed in biofuel production and to the the price of world cereals.

For a more detailed analysis, Gerber *et al.* (2008) provide an exhaustive overview of studies that investigate the relationship between biofuels and food prices both from a historical perspective and with future-looking simulations. The debate concerning the impact of biofuels on agricultural commodities is ongoing. The initial enthusiasm that was associated with biofuels as an alternative to oil has been curbed by the justified concerns related to their potential implications on the global supply of food. In order to make more of the grains and oilseeds employed for biofuel production available for food and feed, Von Braun (2008) called for a freezing or a reduction in current biofuel production until prices drop to long-run levels. Countries such as China have revised their initial plans and the need for second generation technologies has gained greater emphasis.

In the fall of 2008 food prices declined significantly. By March 2009 crop production exceeded expectations and the stocks of most grains and oilseed were rebuilding. Abbott *et al.* (2009) review the predictions of their previous study but maintain that the major drivers of agricultural prices are the depreciation of the US dollar, changes in production and consumption as well as growth in biofuel production. Between spring 2008 and

February 2009 each of these driving forces reversed direction. The anticipated production shortfall did not materialize. Grain and oilseed prices dropped sharply, though they remained above long-term levels and are not likely to return to their 1998-2005 values.

The next section discusses in detail the current biofuel policies across the world and provides a complete overview of the increasing effort made by governments to establish a biofuel industry, thus portraying the global relevance of biomass in finding an alternative to our oil-dependency in the transport sector.

3 Biofuel Policies

Governments across the world have incentivized the evolution of our energy consumption from fossil fuels towards renewable alternatives. Biofuels in particular have been at the receiving end of increased attention and funding. Despite the high price of oil that make the use of biofuels relatively cheaper, their production costs are still too high to compete with gasoline and diesel at a profit (OECD/ITF 2008). Several policies have been introduced in order to create the necessary infrastructure and foster the development of a biofuel industry from infancy to a mature and solid status. The most elaborated forms of support are granted by the US and the EU. Brazil enjoys the most advanced and cost effective bioethanol program in the world and it does not provide direct financial aid, but it required years of governmental assistance until it recently became cost-competitive (World Bank, 2008).

Support is granted through several policies, whose form and implementation may vary across countries. Generally the aim is to incentivize production, strengthen consumption and improve the infrastructure of distribution and retail. Research and development are also promoted in order to decrease manufacture costs, correctly estimate the impact of biofuels on the environment and find alternative feedstock materials to food crops. Despite the variety of programs across the globe, they all share common elements. Governments can intervene on the production chain by supporting intermediate inputs (feedstock crops[26], energy and water) or subsidising the value-adding factors (labour, capital, and land). Production is also helped through instruments that target end-products. In Europe and in the US biofuels receive the greatest amount of governmental subsidies through tax exemptions for blenders. Import tariffs also play an important role by protecting national industries from external competition, even though such policies hurt the customers. Consumption and demand for biofuels are the direct objective of nation-wide policies as well. Mandatory blending requirements are widely included in energy policy programs. Governments have also been directly involved in the construction of plants and in the improvements of infrastructures such as terminals and retail facilities. The whole biofuels production cycle has been targeted for the successful switch from oil consumption to a substitutive fuel. Whereas the type of support may differ across countries, the objective remains the increment of biofuels production and a gradual decline in oil consumption.

The European Union, the United States and Brazil are the world's largest biofuels producers. Their support policies are presented next. A shorter compendium on biofuel aid programs in India, China, Canada, Australia, Thailanad, Malaysia, Indonesia, Japan, South Korea and South Africa is also included.

[26]Subsidies on feedstock are potentially very important, since feedstock accounts for more than half of the cost of production. Rajagopal and Zilberman (2007).

3.1 The European Union

In December 2008 the parliament of the European Union endorsed a binding target of 20% share of renewables in energy consumption and a 10% binding minimum target for biofuels in transport by 2020 as part of the **EU Directive on Renewable Energy**. The official decision followed a proposal published in January 2008[27]. June 2010 marks the deadline for EU states to present National Action Plans on renewables[28].

Previous policies have gradually tried to increase the EU's focus on alternative sources of energy. The 2001 **Directive 2001/77/EC**[29] set a 12% target for gross national energy consumption to be derived from renewables by 2010. Each member state was assigned an indicative reference value of national electricity to be produced from renewable sources in order to achieve the Community's goal of 22.1%. Individual countries were required to be able to guarantee the origin of the electricity produced if asked upon, reduce administrative barriers, integrate grid systems and develope national aid plans. In 2008 the European Commission expected that a share of 19% - rather than the 22% proposed - will be reached by 2010[30].

The 2003 **Directive 2003/30/EC**[31] focused its attention on the promotion of biofuels or other renewable fuels for transport and set a 5.75% target of market penetration by 2010. Each country was asked to aim at an indicative 2% share by 2005. However, in 2005 biofuels accounted for only 1% of transport fuels. Similarly the 2010 goal is likely to be missed, with an expected share of 4.2%[32].

The 2003 Directive did not establish binding targets, though several countries decided to make the 5.75% mark mandatory: Austria, Finland, Germany, Luxembourg, the Netherlands, Slovakia, Spain and the UK set their respective objectives as obligatory.

In the EU biofuels are mainly supported through tax reductions or exemptions. Following the Directive 2003/30EC that established each state's target, the European Union published **Directive 2003/96/EC on Energy Taxation**. The latter specified the tax incentives allowed for the promotion of biofuels and for the achievement of the targets

[27] Proposal for a Directive of the European Parliament and of the Council on the promotion of the use of energy from renewable sources [COM(2008) 30 final], 23.1.2008.

[28] See for current time-line *http://www.euractiv.com/en/energy/eu-renewable-energy-policy/article-117536*

[29] Directive 2001/77/EC of the European Parliament and of the Council on the Promotion of Electricity Produced from Renewable Sources in the Internal Electricity Market, 27.9.2001.

[30] Proposal for a Directive of the European Parliament and of the Council on the promotion of the use of energy from renewable sources [COM(2008) 30 final], 23.1.2008.

[31] Directive 2003/30/EC of the European Parliament and of the Council on the promotion of the use of biofuels or other renewable fuels for transport, 8.5.2003.

[32] Data disclosed in the "Proposal for a Directive of the European Parliament and of the Council on the promotion of the use of energy from renewable sources" [COM(2008) 30 final], 23.1.2008.

set by the common agenda. Tax exemption can be carried out by single countries after approval of the EU Commission. The exemptions are expected to be proportionate to the blending levels and should account for raw material prices in order to avoid over-compensation. Tax exemptions are limited in duration to six years but may be renewed.

According to Kutas *et al.* (2007), in 2006 the total revenue loss due to tax exemptions amounted to 2.9 billion across member countries. **Germany** endured the largest deficit with a staggering 1.98 billion. Budget constraints eventually led the German government to abolish excise duty exemptions as a form of subsidies. This is a particularly important passage, as Germany is the world's main producer of biodiesel and Europe's leading member state in terms of productive capacity and fuel market penetration.

Starting from the 1st of January 2007, Germany eliminated fuel excise tax exemptions and replaced them with quota obligations and tax rebates[33]. Fuel suppliers are required to provide a given share of biofuels in the total amount delivered to the market. Diesel must contain at least 4.4% of biodiesel starting in 2007. The bioethanol content of gasoline must be at a minimum of 1.2% in 2007 and gradually rise to 3.6% by 2010. Percentages are measured in terms of energy content and not in terms of volume.

In addition to the above mentioned shares, in 2009 manufacturers are required to supply a quota of biofuels equivalent to 6.25% of their total production. This percentage is meant to increase over time and reach the 8% mark in 2015. Producers are free to decide how to achieve the above shares. Biodiesel or bioethanol used as additives are taxed with the normal rate for the fuel they are blended with. Tax exemptions are replaced by tax rebates only for pure biodiesel on the amounts exceeding the imposed quotas. The pure biodiesel rebate scheme is valid until the 31st December 2011. On the other hand, pure ethanol and E85 exceeding the quotas enjoy excise tax exemptions.

This support scheme has drawn heavy criticism from German biofuels producers. According to Peter Schrum, president of the German renewable fuels industry association BBK, the tax increment caused drastic reductions in production with Germany's biodiesel industry working at only 10% of its capacity in early 2008. Initial government plans to subsidize biofuels and increment production was followed by capacity expansion. However, the expansion of productive facilities was later matched by reduced

[33]See "State aid No N 57906 - Germany and the European Commission Document C(2006)7141", published on the 20.12.2006 in reference to "State aid No N 579/06 - Germany; Tax rebates for biofuels (amendments to an existing scheme)" and available at *http://ec.europa.eu/comm/competition/state_aid/register/ii/by_case_nr_n2006_0570.html#579*.
The official law passed in Germany actually refers to slightly higher quotas compared to the amount reported in the above mentioned document sent to the European Commission. The official mandatory data passed by the German parliament refer to "Gesetz zur Einfhrung einer Biokraftstoffquote durch nderung des Bundes-Immissionsschutzgesetzes und zur nderung energie- und stromsteuerrechtlicher Vorschriften (Biokraftstoffquotengesetz - BioKraftQuG)" and available at *http://www.biokraftstoffverband.de/downloads/455/BioKraftQuG*.

governmental support and increased taxation. In early 2008 Schrum stated: "a large number of German biodiesel plants will be dismantled, packed in containers and shipped abroad[34]." He further added that the blending requirements are not helping national industries, as blending fuels are usually imported from the cheapest source: "over 90 percent of biodiesel used for blending in Germany is imported." In addition, companies often make a stop over the US before importing the fuel in Germany in order to gain US biofuels subsidies. The EU is expected to place an anti-dumping tariff, as Micheal Hogan reports[35]. The German government has taken the matter in its own hands, and the legislation should be modified. The *Bundeskabinett*[36] has approved to reduce the supply of aggregate biofuel output required from producers. From 2009 the 6.25% mark should drop to 5.25%. From 2010 the share should increase to 6.25% and remain at this level until 2014. In 2011 the quota measures will be reviewed. Taxation of pure biodiesel should also be reduced by 0.03 per liter with the duty level dropping from 0.21 to 0.18 per liter from 2009.

Whereas German policies play a particularly important role given the country's leading position in the European market, there is a plethora of other instruments that individual member states have put in place. In 2006 **France** had the second largest installed production capacity of biodiesel (15% of the EU total versus 54% for Germany) and the second highest level of consumption (14% of the EU total versus 63% for Germany).

The French government's biofuel policies are two-folded. On one hand, the administration has set specific shares of total output to be obtained from alternative fuels. In 2007 the targeted 3.5% quota of biofuels incorporation was reached (Henard, 2008). The biofuel share is meant to increase to 5.75% in 2008, 6.25% in 2009 and 7% in 2010. Finally, the government proposed the attainment of the 10% mark by 2015[37].

The second part of the French biofuel policy is based on fiscal incentives. Annual production quotas benefit from partial tax exemptions. Taxes within the production limit for biodiesel are reduced by 0.25 per liter in 2007 and 0.22 per liter in 2008. Similarly, for bioethanol the exemption is equivalent to 33 per hectoliter in 2007 and 27 per hectoliter in 2008 (Henard, 2008). The duty cuts are reviewed annually. Production quotas are allocated through tenders published in the *Official Journal of the European Union* (Kutas et al, 2006). All manufacturers within the EU can participate in the tender. If successful, they are attributed production quotas for six years[38].

[34]Quoted by Michael Hogan, "German Biodiesel Ouput Collapses" published by *Reuters* on 15/01/2008.

[35]Idem as 34.

[36]*Bundeskabinett beschließt Gesetz zur Änderung der Förderung von Biokraftstoffen* published on the 22.10.2008 by the Bundesministerium fr Umwelt, Naturschutz und Reakorsicherheit and available at *http://www.bmu.de/pressemitteilungen/aktuelle_pressemitteilungen/pm/42433.php*.

[37]Percentages are measured in terms of energy content (or net calorific value).

[38]to Kutas *et al.* (2006), 27 operators were approved for production of biodiesel. Some of these quotas were assigned to manufacturers outside of France; i.e. in berlgium, Germany, Italy and Spain.

Italy is the third largest producer of biodiesel in the EU and it has the third highest installed manufacturing capacity. The Italian legislation provides tax exemption for given production quotas of 200,000 tonnes of biodiesel (equivalent to 227 million liters). The decree is valid until the 31.12.2010. More recent legislation has set mandatory blending targets of biofuels. According to the *Legge Finanziaria 2007*, in 2007 there was an obligatory 1% biofuel blending share of total production, which is meant to increase to 2% in 2008. The *Legge Finanziaria 2008* set a mandatory 3% target for 2009 (Nomisma Energia, 2008). Whereas these objectives comply with the European 2003/30/EC directive of reaching a 5.75% share by 2010, this target is most likely not to be met due to the insufficient potential availability of land and the current trends in the Italian biofuel industry (Nomisma Energia, 2008).

Spain has the fourth highest installed biodiesel capacity and is the third largest ethanol producer across EU member states. Aided by the relatively low biofuel output that does not influence greatly its budget, Spain promotes a total tax exemption for biodiesel and bioethanol[39]. Duty exemptions are meant to be in place until 2012[40].

The various subsidy programs related to the fuel excise duties can be summarized as follows. Complete tax exemptions are a policy commonly adopted by EU countries that do not have a particularly high biofuel production, thus limiting the impact that the foregone income has on their financial plans. Austria, Cyprus, Estonia, Hungary, Latvia, Lithuania, Slovakia, Spain and Sweden granted full tax exemption on biodiesel and bioethanol in 2007. The Czech Republic and Denmark imposed no taxes on biodiesel. Malta, the Netherlands, Poland, Slovenia and the UK offered some form of tax reduction (Kutas *et al.*, 2006).

A quota system has been adopted in order to better control for the quantity of tax revenue lost due to exemptions. Belgium, France, Italy, Ireland and Portugal offer full or partial exemptions on biodiesel and bioethanol[41], but only up to given production levels (Kutas *et al.*, 2006).

Germany grants full exemptions only for pure biodiesel and E85 and has imposed mandatory blending quotas. Luxembourg require no excise duties only from pure biodiesel. Finland, Germany, Greece and Luxembourg are the only EU25 member countries that do not grant any tax exemptions for blends with low biofuel content (as of 2007).

The reduction or elimination of excise duties is the most “expensive” form of subsidy, but it is not the only one. Two more policies play a particularly important role for the

[39] See European Biodiesel Board at *http://www.ebb-eu.org/legislation.php.*

[40] Duty exemptions apply uniquely to the volume of biofuels produced, even if the latter are blended with other fuels.

[41] Italy actually does not provide tax exemptions for bioethanol based on a quota system.

development of a European biofuel industry: the Common Agricultural Policy and EU import tariffs.

Import tariffs for Most Favored Nations (MFN) amount to a 6.5% *ad valorem* duty for biodiesel[42]. There are however little imports of biodiesel, of which the EU is the world's leading producer (UNCTAD, 2006)[43]. Vegetable oil for biodiesel production can enter for "industrial use" as "crude soy oil," "crude sunflower oil" or "crude rape oil" and face a tariff of 3.2%. Alternatively, "crude palm oil for industrial use" has no inbound duties (Kutas *et al.*,2006). Imports of ethanol are substantially larger and amounted to 250 million liters in the 2002-2004 period. It should be noted that ethanol is used for a variety of end-products other than fuel blending. About 30% of imported bioethanol came from MFN countries under the classification of "denatured alcohol" at a levy of €0.102 per liter or as "undenatured alcohol" €0.192 per liter[44]. Preferential treatment is granted to less developed countries, which enjoy reduced or no duties. This refers to countries belonging to the Generalized System of Preference (GSP), Cotonneou Agreement (ACP) and Everything But Arms (EBA). In 2006 the membership to GSP nations was changed and Pakistan, previously a competitive exporter that supplied 20% of the EU ethanol imports, lost its duty-free access to the EU market and lost its competitive advantage (UNCTAD, 2006).

The **Common Agricultural Policy** (CAP) is a long standing aid program aimed at helping farmers, fostering the quality of food and protecting rural areas[45]. The program currently costs around 55 billion euros annually and it drains more than 40% of the EU's budget[46]. In 1992 a CAP reform[47] was introduced in order to reduce surpluses in the production of cereals and oilseeds. The regulations set up lower intervention prices that were compensated according to crop type and to mandatory fixed shares of "set aside" land. Farmers were required not to plant food crops on specific portions of the farmland. The use of "set aside" soil was then allocated for alternative ends and energy-crops were particularly favored: more than 95% of non-food "set aside" regions were allocated to energy crops[48].

In accordance with the EU's attempt to develop biofuels, a further CAP reform in 2003[49] maintained obligatory shares of non-food "set aside" land and added direct aid for energy crops. For a maximum guaranteed area of 1.5 million hectares, an incentive

[42] Biodiesel enters the EU borders under the item "other chemicals".

[43] Mostly they are inter-state trade and import/export.

[44] Brazil was the largest MFN exporter, with a 25% quota of the total EU imports.

[45] See the EU commission page on the CAP at *http://ec.europa.eu/agriculture/lisbon/index_en.htm.*

[46] See the EU's web page on agriculture at *http://europa.eu/pol/agr/index_en.htm*, and especially the presentation on "The Common Agricultural Policy Explained."

[47] Council Regulation (EEC) No 1765/92 - the Mac Sharry reform

[48] "Report from the Commission to the Council on the Review of the Energy Crops Scheme," COM(2006) 500 final, 22.09.2006.

[49] Council Regulation (EC) No 1782/2003

of €45 per hectares is granted to growers of energy crops. The two incentive systems run in parallel and farmers may opt for either regime[50] depending on their specific circumstances.

The 2003 amendment also introduced Single Payment Schemes (SPS), thus decoupling producer support from production decisions. Compensations for "set aside" land were also included in the SPS scheme. This prevents us to determine the amount perceived by farmers for their portion of "set aside" areas. Kutas *et al.* (2006) however estimate that in the 2000-2002 period the average contribution received for "set aside" regions was €290 per hectare.

In May 2008 the EU decided on a new reform of the CAP[51]. Mandatory "set aside" was suspended. In the light of potential food shortages and rising prices, the policy's original objective to eliminate cereals surpluses is obsolete. Direct payments remain decoupled from production decisions.

3.2 The US

The US is the biggest manufacturer of fuel ethanol in the world. Its production is highly subsidized and almost uniquely based on corn (Schnepf, 2005)[52]. The RFA[53](2008) measures total US output to amount to 24.6 billion liters in 2007, while Brazil trails with 19 billion liters. Europe is far back with its 2.1 billion liters in third position, followed by China with 1.8 billion liters (see Table 3).

There is a myriad of support and incentive programs both at the federal and at the state level, which render it difficult to estimate the aggregate impacts on the economy or to calculate the total value of funding invested. Koplow (2006) finds that ethanol received between US$5 and US$7 billion dollars in subsidies in 2006. According to Hahn (2008), "in absolute size, these subsidies are lower than the subsidies given to energy sources such as fossil fuels and nuclear fission, but the subsidies exceed all other government subsidies to energy in per unit energy terms."[54]

In 2007 President Bush started an aggressive campaign to reduce its country's dependency on oil. One of the flagship mottos of the **Energy Independence and Security Act** of 2007 is to reduce gasoline consumption by 20% in the next 10 years. The **Biomass Program**[55] aims to tackle directly feedstock production and logistics, biofuels produc-

[50]are not entitled to both support schemes at the same type.

[51]Proposal for a Council Regultion (EC) COM(2008) 306 final, 20.05.2008.

[52]Schnepf(2005) estimates that around 90% of US ethanol is produced uniquely from corn.

[53]Renewable Fuels Association, RFA, 2007 World Fuel Ethanol Production, citing as source F.O. Licht, (2008). Available at *https://www.ethanolrfa.org/industry/statistics/#E.*

[54]Hahn (2008), page 6.

[55]DOE, Biomass Multi-Year Program Plan, (March 2008), available at *http://www1.eere.energy.gov/biomass/pdfs/biomass_program_mypp.pdf.*

tion and distribution as well as its end use. Ultimately the target is to displace 30% of 2004 gasoline by 2030.

The most important intermediate goal is to make cellulosic ethanol cost competitive with corn- or maize-derived ethanol. This step is to be achieved through R&D and aims to reach 2nd generation ethanol costs for "mature technology[56]" at US$1.33/gallon by 2012 and US$1.20/gallon by 2017. The **Energy Policy Act** of 2005 requires 250 million gallons of cellulosic ethanol to be produced by 2013. Hahn (2008) quotes an outline of the **Advanced Energy Initiative**, which includes initiative grants of about US$150 million to help develop 2nd generation bioethanol. In 2007, US$385 million were distributed by the Departmant of Energy to fund six cellulosic ethanol plants[57].

However, these are small figures compared to the expansion of productive capacity that is underway in the corn-based bioethanol industry. Given the 134 ethanol plants existing as of December 2007, a further 66 factories are under construction and 10 are expanding (Hahn, 2008; RFA, 2008). Current total capacity of more than 7 billion gallons a year is estimated to surpass 13 billion gallons a year once construction is completed. With respect to biodiesel, capacity should increment by 200% over the next few years. Koplow (2006) estimates a US$10 billion total investment in ethanol production facilities since 2000, whereas the corresponding measure for biodiesel amounts to US$1.8 billion.

Capacity expansion is matched by monetary incentives for production. The main source of financial support is the **Volumetric Ethanol Exercise Tax Credit** (VEETC), (Koplow, 2006). The VEETC is guaranteed for every domestic or imported gallon of ethanol blended with other fuels. It is awarded without quantity limits and independently of the price of gasoline (Koplow, 2006). Blenders can claim 51 dollar-cent credit per gallon used (EIA, 2008). The incremental use of biofuels in the economy implies an always greater impact of this tax credit. The Energy Information Administration (EIA, 2007) estimates that the tax credit costed around US$2.4 billion in 2006. If the annual production of ethanol exceeds 11 billion gallons in 2010 as estimated by the EIA (2007), the tax credit alone would cost the government almost US$5 billion. This may lead to reconsideration of the subsidy level.

The volumetric tax credit was enacted in 2004 by the **American Jobs Creation Act** and it is scheduled to expire in 2010. The latter is the latest of a series of policies initiated in 1978 with the **Energy Tax Act**, which provided tax credits for ethanol blenders. Over the decades different degrees of credit have been guaranteed, though

[56] Mature technology refers to costs when several plants have been built and are operating successfully so that additional costs for risk financing, longer start-up and other costs associated with pioneer plants are not included.

[57] Hahn (2008) quotes the "DOE, DOE Selects Six Cellulosic Ethanol Plants for Up to US$385 Million in Federal Funding", February 28 (2007), available at *https://www.energy.gov./news/4827.htm*"

some form of subsidies has been present ever since and it is expected to continue. Another milestone in the development of the US ethanol industry was the 1990 **Clean Air Act Amendments**, which mandated the adoption of oxygenated fuels in areas with too high carbon monoxide levels (Hahn, 2008). Either ethanol or methyl tertiary butyl ether (MTBE) were used by blenders to add oxygen to gasoline in order to lower the engine's carbon monoxide emission. Whereas initially MTBE was the oxygenate of choice, following claims of cancerous groundwater contamination it was later supplanted by ethanol.

The 2004 American Jobs Creation Act also guarantees tax credits for biodiesel under the VEECT. The subsidy amounts to US$1 per gallon for biodiesel produced from virgin oils or fats, and US$0.50 per gallon for recycled oils. Given the lower output of biodiesel, the corresponding governmental loss is also inferior. Koplow (2006) estimates that the foregone tax revenue for 2008 would reach almost US$1.5 billion.

It is important to notice that the VEETC is a federal law that is further augmented by a variety of state-specific subsidies, which play a particularly important role in the mid-west region, where most of the corn destined to ethanol production is grown[58]. The incentives to make biofuels from corn are such that 20% of the available US corn supply was employed as ethanol feedstock in 2006 (EIA, 2007).

Small ethanol producers are specifically targeted by the Energy Policy Act of 2005. Firms with an output up to 60 million gallons are allowed an income tax credit of US$0.10 per gallon on production volumes up to 15 million gallons (EIA, 2008). Even though this subsidy affects a relatively small number of businesses, it is meant to protect and foster the national industry.

However, a much more efficient form of protection is guaranteed by import tariffs. There are two taxes levied against imported ethanol. The first one is an *ad valorem* tariff of 2.5 percent. Afterwards a further duty of US$0.54 per gallon is applied under the Most Favoured Nations (MFN) scheme[59]. This policy substantially hinders Brazil's ability to compete within the US ethanol market. Brazil sugar-cane ethanol has lower costs of production and the output capacity to be imported in the North American market. The import tariff effectively limits this competitive advantage and partially contradicts the goal of increasing national ethanol consumption (Hahn, 2008). North America Free Trade Agreement (NAFTA) members (Canada and Mexico) can export ethanol to the States on a duty-free basis. Limited duty-free imports are allowed from countries of the Caribbean Basin Economic Recovery Act (CBERA), as long as their exports do not surpass 7% of domestic production. Koplow (2006) reports that this constraint has not been binding.

[58]For a review of individual state policies see Koplow (2006).

[59]The US$0.54 import duty prevents imported ethanol from benefiting from the subsidy for domestic producers.

A further attempt to strengthen the adoption of biofuels is through policies that target demand and mandate the attainment of specific consumption levels. The Energy Policy Act of 2005 introduced **Renewable Fuel Standards** (RFS), which require obligatory use of fixed levels of liquid biofuels. In 2006 the target was to consume 4 billion gallons of renewables. By 2012 this figure has to rise 7.5 billion gallons.

The Energy Independence and Security Act of 2007 expanded the RFS requirements to consume 36 billion gallons of ethanol by 2022. From 2015 onwards, the maximum amount of corn-ethanol to be produced is 15 million gallons. In addition, corn-ethanol has to achieve a reduction in life-cycle GHG emissions of 20%[60]. Biofuels are set to reach a consumption level of 0.5 billion gallons in 2009, eventually rising to the 1 billion gallons in 2012. Cellulosic biofuels are expected to amount to 0.1 billion gallons in 2010 and steadily surge to 16 billion gallons by 2022 (EIA, 2008).

Finally, consumption of ethanol is directly proportional to the engine requirements and the availability of fuels with high alcohol content. Since the 1970's all gasoline powered vehicles sold in the US can run on E10[61], (Koplow, 2006). Flexi-fuel vehicles (FFV) are warranted to run on blends with higher ethanol content such as E85[62]. The 1988 **Alternative Motor Fuels Act** (AMFA) helps automakers counterweight Corporate Average Fuel Requirements (CAFE) when they manufacture vehicles that run on alternative fuels (Koplow, 2006). The latter has favoured the production of Flex-Fuel vehicles. According to the EIA (2007), 5 million FFV were produced in the US between 1992 and 2005. However, the advantages in ethanol consumption provided by this type of cars is hindered by the limited availability of stations that provide E85 blends. Only 0.5% of all fuelling stations actually offer E85 (EIA, 2007). In addition, most of these facilities are located in the Midwestern region, half of the total stations being in Minnesota alone (Koplow, 2006).

Nonetheless, in order to foster the market penetration of Flex-Fuel vehicles, the CAFE credit program specified under AMFA has been extended until 2019. The Energy Independence and Security Act of 2007 also promulgated that a new and more stringent CAFE standard for cars and light truck vehicles will be introduced commencing in 2020 (EIA, 2008).

In order to improve the current distribution of ethanol blends across the country, a set of policies is also in place. Ethanol cannot be transported through pipelines that carry only petroleum products. Fuels with high ethanol content such as E85 need corrosion resistant tanks and other specific equipment. Under the Energy Policy Act of 2005, 30%

[60]In California corn-based ethanol does not qualify as a fuel that sufficiently reduces GHG emissions. Corn-based ethanol/gasoline blends are not considered low carbon fuels (see the Low Carbon Fuel Standard enacted by the California Air Resource Board in May 2009).

[61]E10 stands for fuels with 90% gasoline and 10% ethanol.

[62]In E85 fuels ethanol content is 85%.

of eligible costs of depreciable property up to a maximum of US$30,000 are granted for installing tanks and equipment for E85 (Koplow, 2006)[63]. However, in this case as well, the federal subsidies are extended by state-specific incentives and policies that render difficult an estimation of the total credit granted through this policy.

3.3 Brazil

Brazil has the most developed and integrated biofuels program in the world. Its initiation dates back to the first oil crisis in 1973. In 1975 Brazil introduced the **National Alcohol Program Proàlcool** focusing on the production of anhydrous (or pure) ethanol from sugar cane to be blended with gasoline. The objective was to limit energy supply constraints, provide a stable internal demand for the excess production of sugar cane and counterweight variations in international sugar prices (Walter and Cortez, 1999). Following the second oil shock in 1979 the government extended the program to large scale production of hydrated ethanol (95% ethanol and 5% water). The latter required a specially designed engine and agreements with manufacturers were made to develop a market for purposely modified vehicles. The construction of distilleries including many autonomous facilities, concentrated in the São Paulo State and kept pace with the rising national trends. While production shifted toward hydrated ethanol, the plan proved successful and 96% of automobiles sold in Brazil in 1985 were ethanol powered (Colares, 2008). The initial triumphs were soon displaced by the decline of oil prices that followed 1985. Sales of ethanol powered vehicles plummeted to 1% by the late 1990s and the over-valuation of Brazilian currency (1994-1999) increased ethanol production costs. The government tried to limit these drawbacks by implementing legislation in 1993 that required a 22% ethanol content added to gasoline. In 2003 this percentage was raised to 25%. During the 1990s further deregulatory legislation in the energy and fuel markets contributed to the future successes of the program. In 1998 the government liberalized the price of hydrated alcohol to be used in fuels and in 1999 it stipulated that hydrated ethanol fuel sales were to be carried out through public auctions[64]. The surge in oil prices that characterized the 2003-2008 period brought ethanol back to its initial success. Ethanol became once again a cheap and sought after alternative to oil. Furthermore, the introduction of Flex-Fuel engine technology, which allows drivers to run on gasoline or on ethanol, contributed to this resurgence. In 2006 83% of the cars sold in Brazil were Flex-Fuel Vehicles (FFV) and the country achieved oil independence (Colares, 2008). According to De Almeida's *et al.* (2008) estimates, "FFVs could make up 27% of the Brazilian car fleet in 2010 and 43% in 2015"[65]

The success of the Proàlcool program is reflected in the importance that sugar and ethanol production play in the Brazilian economy: The two industries account for 3.6 million jobs and 3.5% of GDP, while ethanol production alone consumes 50% of the total sugarcane supply (de Almeida *et al.*, 2008).

[63] Koplow (2008), page 43.
[64] World Trade Organization, Trade Policy Review - Brazil 2008, (2005).
[65] De Almeida's *et al.* (2008), page 156.

The relevance of Brazilian biofuels production goes beyond its national borders. Brazil's ethanol is recognized as the most price-competitive biofuel in the world. Several studies have tried to estimate its production costs. Among the most recent contributions, Macedo and Nogueira (2005) calculated ethanol costs in the Centre-South region of Brazil at US$0.23 per liter. Kojima and Johnson (2006) measured average production costs to be between US$0.23 and US$0.29 per liter. These values would make ethanol competitive with oil prices at about US$30 per barrel. De Almeida *et al.* (2008) estimate an average production cost of new ethanol projects to be around US$0.37 per liter. In this case an oil price of US$42 per barrel would make ethanol cost-competitive.

Brazil's low manufacturing expenses are the result of several elements. First of all the fundamental production feedstock, sugarcane, is relatively cheap. High levels of land productivity are combined with almost no needs for irrigation. In addition, the mills are able to satisfy almost all of their energy needs through co-generation power plants based on bagasse (de Almeida *et al.*, 2008). Bagasse is a by-product of sugarcane, it is estimated that one tonne of sugarcane generates 280 kg of bagasse, 90% of which is employed as feedstock for heat and power generation. Finally, several years of governmental support allowed large investment in research and technology developments that perfected the transformation processes and lowered manufacture costs.

As of today, however, there are **no direct subsidies for ethanol production**. The government maintains nonetheless preferential treatment of the ethanol industry compared to gasoline producers. Since 2004 ethanol does not face any excise tax. Federal duties are also much higher for gasoline, which is charged at US$0.26 per liter, compared to US$0.01 per liter for ethanol. Fuel's VAT is determined by state regulation and varies across the country. In Sao Paulo State, where most of production is located, the VAT component of gasoline's consumer price is 47%, while ethanol's duty remains at 22%. In the Rio de Janeiro State the difference is lower, with the VAT on gasoline accounting for 50% of the consumer's price compared to 36% for ethanol. De Almeida *et al.* (2008) estimate that ethanol enjoys tax incentives for a total value of US$977 million per year. They also calculate that between 1979 and the mid-1990s government support amounted to around US$16 billion. These numbers remain relatively small compared to the level of subsidies granted by the US for ethanol as estimated by Koplow (2006).

The low cost of production enjoyed by Brazilian ethanol would potentially make the industry a competitive exporter to the US, which has a relatively developed internal market with high domestic production costs. However, US import barriers limit this flow, as ethanol coming into the States from Brazil is further charged a levy of US$0.54 per gallon. Due to this reason a significant share of Brazil's exports to the US transit through third countries (such as the Caribbean Basin Initiative) that are granted duty exemptions from the US government. Total exports amount to 3.5 billion liters. The US is the main destination and it receives around 60% of the total (including ethanol transiting through third countries). Other relevant destinations are the Netherlands (10%) and Sweden (6%).

Based on the successful experience of the bioethanol plan, Brazil is now also investing in Biodiesel. The **National Program on Biodiesel Production and Usage** (PNPB) was inaugurated in 2005. PNPB requires 2% of petrol based diesel to be replaced by biodiesel from 2008 to 2012. This share shall increase to 5% from 2013 onwards (Colares, 2008). In order to meet the required consumption shares a large capacity expansion is underway. There are 63 plants currently being constructed, whose future production has to be added to the 21 biodiesel plants already operating. The total expected output level would reach the 4 billion liters once the projects are terminated[66].

Brazilian biodiesel production is mostly based on soybean, though other important vegetable oil plants are castor bean, palm tree and jathropa. Contrary to ethanol, biodiesel is not cost-competitive and it is subsidized. There are two main support schemes. The first one refers to auctions organised by the government, where the National Petroleum Agency (ANP) buys given quantities of biodiesel to ensure supply targets. The prices paid in the auctions have been much higher than production costs, thus stimulating supply. Subsidies in the ANP auctions totalled US$180 million. The second form of assistance is granted through tax exemptions with a focus on the regional location of production and on the provenience of the feedstock. Normal diesel fuels are charged a federal tax of US$0.10 per liter. Biodiesel produced in the North and North-Eastern region from castor bean and palm oil plantation can enjoy reduction of 31% on the tax for common diesel. Additionally, biodiesel manufactured from feedstock produced by small farmers is granted a 68% tax exemption all over the country (de Almeida *et al.*, 2008).

3.4 India

India is the fourth largest producer of ethanol. Its government has recently set new biofuel targets. By 2017 an indicative 20% share of biodiesel and bioethanol shall be blended with mineral diesel and gasoline respectively[67].

In 2003 the Ministry of Petroleum and National Gas initiated the **Ethanol Blended Petrol** (EBP) program. Mandatory blending of 5% ethanol was required in nine states (out of 28) and four union territories (out of seven)[68]. Ethanol is to be manufactured from sugarcane, but initial reductions in the feedstock supply hindered production. Sugarcane availability increased from 2006 after the government stipulated arrangements between the sugar industry and oil companies. The second phase of the EBP commenced in

[66] De Almeida *et al.* (2008), page 176.

[67] As reported in an article by Rajkumar Ray and Mayank Bhardwaj, *India sets new biofuel target, risks food price row*, published by Reuters on the 11.09.2008 and available at *http://in.reuters.com/article/economicNews/idINIndia-35429120080911.*

[68] Sing's (2007) GAIN report from which this information is taken actually refers to a total of 29 states and 6 union territories (which are then later changed to eight).

September 2006. Ethanol blending at 5% was extended to 20 states from November 2006. Once the blending requirements will have been successfully extended to all states, the government plans to initiate a third stage of EBP and raise ethanol share requirements to 10%. There are no direct financial tax incentives for this biofuel policy. Subsidized loans are however offered by the government for sugar mills constructing an ethanol production unit (Singh, 2007).

The year 2003 also marked the beginning of the **National Mission on Biodiesel**. The government set to plant jathropa on 11.2 million hectares of wasteland by 2012 and achieve a 10% blending target. Unfortunately, biodiesel is produced at costs that surpass its purchase price (which is predetermined by national regulators on a six months basis), thus effectively hindering the ambitious targets initially proposed. In particular, there are limited direct tax incentives for the production of the fuel. The government has eliminated the central excise tax for biodiesel, but most state administrations have maintained the state excise duty (Singh, 2007)[69]

3.5 China

China's biofuel production focuses on grains derived ethanol. In 2007 it produced 1.8 billion liters of fuel ethanol (Table 3) with maize constituting about 80% of its feedstock (GSI, 2008). The **Ethanol Promotion Program** was launched in 2002 in order to make use of excessive maize stock-piles. Biodiesel, on the other hand, has not been directly promoted by the government (despite the fact that diesel is the predominant transport fuel) as China is a net importer of vegetable oils.

In 2006 the National and Development Reform Commission (NDRC) proposed in the **11th Five Year Plan** the ambitious goal of 6.6 billion liters of biofuel output by 2010[70]. However, the proposal was not approved by the State Council (Latner *et al.*, 2007). The decision followed concerns over rising food prices.

In August 2007 the NDRC announced a **Medium and Long Term Development Plan for Renewable Energy**. Renewable energy as a share of total primary energy consumption shall rise to 10% by 2010 and to 15% by 2020. Biofuels play an important role in the achievements of these targets. Ethanol production is projected to reach 2 million tonnes by 2010 and 10 million tonnes by 2020. Biodiesel consumption should correspond to 200,000 tonnes by 2010 and 2 million tonnes by 2020 (GSI, 2008).

[69]For a greater exposition of India's status on biofuels also look at Gonsalves (2006a)

[70]Data reported in GSI (2008) as 5.2 million tonnes of ethanol. See appendix for conversion rates.

China is expected to consume around 400 billion liters of oil for transport fuel[71] in 2022. The projected 12 million liters of biofuel output would contribute to only 2.2% percent of the forecasted energy content of oil for transport consumption[72].

Initially the development of a biofuel industry was seen as an option to employ excess grains hold in the national reserves and improve rural income[73]. In 2001 the government issued standards for denatured fuel ethanol and for bioethanol gasoline for automobiles. The beginning of the **State Scheme of Pilot Projects on Bioethanol Gasoline for Automobiles** followed shortly. The success of the pilot projects led the **National and Development Reform Commission** (NDRC) to extend the project and in 2004 it initiated the **State Scheme of Extensive Pilot Projects on Bioethanol Gasoline for Automobiles** (SSEPP). The scheme included the development of production and retail sites in five provinces and nine cities. The production and distribution was rigidly controlled by the government, which authorized only four companies to manufacture ethanol from grains. In addition, all producers of fuel ethanol had to sell their output either to CNCP or Sinopec, which then blended ethanol with gasoline and distributed E10. As GSI (2008) reports, virtually all petrol stations in China are owned by either Sinopec of CNCP.

At the beginning of 2006, extensive pilots projects carried in five provinces and 27 cities had achieved the substitution target of blended bioethanol with gasoline (Dong, 2007). The vehicles in the pilot cities or provinces were required to use E10. However, in December 2006 the Chinese governments reviewed its policy priorities and questioned biofuel manufacture based on grains. Due to concerns over rising food prices, the proposed 11th Five Year Plan was not approved by the State Council (Latner *et al.*, 2007). The government is unlikely to grant production permission to new factories employing corn or maize feedstock or to authorize capacity expansion. The attention has been switched to non-grain crops such as cassava, sweet sorghum and sweet potatoes. In order for biofuel production not to affect China's food security, the government has emphasized the use of marginal land to produce biofuel crops (GSI, 2008).

The price of fuel ethanol is controlled by the government[74] at a level that would make ethanol production unsustainable without external financial assistance. In 2007 a flat subsidy of US$200 per tonne of ethanol was granted to producers (equivalent to US$0.158

[71] The EIA (2008) provides data for China's Share of Transport in Primary Oil Demand (43% in 2015 and 54% in 2030, p. 99) as well as the Primary Oil Demand in References Scenario (11.6 million oil barrels a day in 2015 and 16.6 million oil barrels a day in 2030, p. 93). This makes an extrapolated average of 2523 million barrels a year (approximately equivalent to 400 billion liters of oil).

[72] Given conversion factors in appendix: 10 Mil tonnes ethanol = 267 Mil GJ; 2 Mil tonnes biodiesel = 75.6 Mil GJ; 2523 million oil barrels = 15390 Mil GJ. Share of biofuel energy content = (267+75.6)/15390

[73] Besides the usual justification for biofuel production such as reducing oil dependancy and improving environmental conditions.

[74] GSI (2008) reports this price to be 0.911 times the ex-factory price of RON (research octane number) 90 gasoline (p. 23).

per liter). From 2008 the fixed subsidy has been replaced by payments based upon an evaluation of an individual plant's performance conducted each year in November (GSI, 2008). The licensed ethanol producers are exempted from the 5% consumption tax and the 17% VAT. Financial assistance is granted to intermediate inputs such as grains and fertilizers. The Ministry of Finance also provides direct support of 2nd generation cultivations with grants amounting to US$438 per hectare of biofuel feedstock plantations such as jathropa and US$394 per hectare of non-grain biofuel crop such as cassava.

No direct subsidies are currently granted for biodiesel. The biodiesel industry is less regulated in comparison to its ethanol counterpart. Production facilities have a generally lower capacity and production is of a relatively low quality. There are no national biodiesel standards, thus preventing the latter from being blended and distributed across the nation by CNCP and SINOPEC. Biodiesel is sold by producing factories directly to end users, thus avoiding consumption or VAT taxation.

3.6 Canada

The Canadian **Environmental Protection Act Bill C-33** mandates a 5% renewable content in gasoline by 2010 and a 2% renewable content in diesel fuel and heating oil by 2012[75]. In order to meet the proposed targets a minimum of 1.9 billion liters of ethanol shall be produced given current trends on the sale of gasoline. By the end of 2009 expected output capacity of ethanol should reach the 1.810 billion liters, while current capacity is estimated to be 1.135 billion liters in 2008 (Dessureault, 2008). A recent report by Myles and Dessureault (2009) states that the ethanol targets may be in jeopardy due to delays in the development of new facilities following cost-cuts in response to the lower oil prices of 2009. The achievement of the 2% biodiesel federal mandate is presumed to require a five-fold increase in the current production capacity and deliver 520 million of biodiesel by 2012 (Dessureault, 2008).

Contrary to the U.S., Canada has not turned its attention to biofuels because of energy security concerns. Canada enjoys the second highest oil reserves in the world (Table 2) and is a net energy exporter (Table 1). The desire to develop alternative markets for its agricultural products, environmental consideration and the large availability of land may motivate the Canadian government's decision.

Ethanol is produced from corn and wheat while biodiesel manufacture relies upon canola (rapeseed) oil, tallow and yellow grease. The biofuel industry is still in its infancy and governmental support is required for its development. Besides the federal share mandate, there are direct incentive payments for production beginning in April 2008.

[75] *The Government of Canada Biofuels Bill Receives Royal Assent*, published in EcoAction on the 26th of June 2008 and available at *http://www.ecoaction.gc.ca/news-nouvelles/20080626-eng.cfm*. Data also reported in Rajagopal and Zilberman (2007) and Steenblick (2007),as announcement of proposed Bill came in December 2006.

Through the **EcoENERGY for Biofuels Program** ethanol manufacturers enjoy a maximum incentive rate of CAN$0.10 per liter for three years from 2008 to the end of 2010. The payment declines by CAN$0.01 every year thereafter until it reaches the CAN$0.04 per liter mark in the 2015, which is also kept for 2016. The maximum incentive rate for biodiesel amounts to CAN$0.20 per liter from 2008 to 2010. The subsidy decreases by CAN$0.04 every year until is valued at CAN$0.06 in 2016. The aforementioned payment scheme replaced the previous excise tax exemption on biofuels.

Several programs are in place in order to encourage biofuel production. The **econAGRICULTURE Biofuels Capital Initiative** (ecoABC)[76] provides repayable contributions for the construction or enlargement of biofuel manufacturing units via a CAN$200 million fund ending on March 2011. The **Agricultural Bio-Products Innovation Program** (ABIP)[77] tries to foster innovative agricultural biomass conversion by mobilizing research clusters thanks to a CAN$145 million multi-year fund. The **Agri-Opportunities Program**[78] allocates CAN$134 million for projects aimed at accelerating the commercialization of agricultural products, services or processes that not yet available commercially in Canada but that can be readily introduced into the market place. The technological gap between first and second generation biofuels is to be overcome with the financial support of funds administered by the **Sustaninable Development Technology Canada**[79], a non-profit foundation that collects several hundred million Canadian dollars in grants from the government.

Trade protection of the national biofuel industry is limited in comparison to current custom polices set in the US and the EU. There are no import tariffs on alternative fuels manufactured in NAFTA countries. There is however a duty of CAN$0.05 per liter on ethanol imports from Brazil.

The federal biofuel mandates and support policies are further integrated by specific legislative measures imposed and financed by individual provinces. Dessureault (2008) provides a detailed account of the various regional polices in place. It is worthy mentioning that several provinces have mandated higher biofuel shares compared to the target established by the central government. For instance, in Manitoba the ethanol share of gasoline is required to be 8.5% from the beginning of April 2008, there are excise fuel tax exemptions for E10 blends and production incentives in the form of direct payments start from a CAN$0.20 per liter in 2008 and eventually decrease to CAN$0.10 per liter by the end of 2015. These amounts surpass the subsidies provided by federal laws. In the Saskatchewan province the ethanol content of gasoline is set at a mandatory 7.5% level since mid-2006.

[76]See *http://www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1195672401464&lang=eng.*
[77]See *http://www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1195566837296&lang=eng.*
[78]See *http://www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1195488674667&lang=eng.*
[79]See *http://www.sdtc.ca/en/about/index.htm.*

3.7 Australia

In 2001 the Australian government set a non-binding target of 350 million liters of yearly biofuel production by 2010. Current transport fuel supply corresponds to around 19 billion liters of gasoline and 17 billion liters of diesel, making the prospected biofuel contribution approximately 1% of the national transport fuel's needs.

Even though the targets established by the federal government are not mandatory, in 2006 the state of New South Wales set a 10% binding share of ethanol in gasoline by 2011 and the state of Queensland required a 5% ethanol content in gasoline by 2011 in their respective jurisdictions.

Australia has a relatively limited biofuel production. According to the Rural Industries Research and Development Corporation[80] in 2007 ethanol processing capacity was 140 million liters and biodiesel production capacity reached the 323 million liters, with planned future capacities in excess of 1 billion liters for both biodiesel and ethanol. Its actual production is much lower and amounted to 83 million liters of ethanol and 77 million liters of biodiesel in the 2006-2007 fiscal year (Quirke *et al.*, 2008).

Despite the low output, biofuels are highly subsidized compared to other Australian industries if measured in Effective Rates of Assistance (ERA), as Quirke *et al.* (2008)report. The most important assistance policy is a tax rebate (the **Ethanol Production Grant** and the **Energy Grants - Cleaner Fuels Scheme**) that exactly offsets fuel excise duty of A$0.38143 per liter for both ethanol and biodiesel until 2011[81].

On the 1st of July 2011 the Ethanol Production Grant will be eliminated, and the actual excise duty will decrease to A$0.125. However, an alternative set of payments will be made via the Energy Grants - Cleaner Fuels Scheme starting with A$0.1 per liter and decreasing by A$0.025 per year until 2015, when it will disappear.

Biodiesel enjoys a similar treatment. From 2011 its excise duty will drop to A$0.191 per liter and the Energy Grant - Cleaner Fuels Scheme will reduce its incentives from the previous A$0.38143 to A$0.153 and continue to decrease until it will be eliminated in 2015[82].

[80] Australian Government Rural Industries Research and Development Corporation, *Biofuels in Australia - An Overview of Issues and Prospects* , (May 2007). Available at *http://www.rirdc.gov.au/reports/EFM/BiofuelsSummaryWEB_READY.pdf* and *http://www.rirdc.gov.au/reports/EFM/07-071sum.html*.

[81] The Euro/A$ exchange rate floated between 1.75 in September 2008, 2.05 in December 2008 and 1.7 in August 2009.

[82] For exact excise duty values for biodiesel and ethanol as well a year by year value of the government's tax incentives see Quirke *et al.* (2008) at p. 32 and p. 45.

The Australian government also provides some custom duties to protect the national industry. Import duties on ethanol (both denatured and undenatured) amount to a 5% *ad valorem tariff* (with the exception of imports from the US) and a A$0.38143 per liter excise duty until 2011 (imported ethanol does not enjoy the governmental subsidy provided by the Ethanol Production Grant). From 2011 onwards the excide duty imposed on imported ethanol matches the effective excise duty paid by national producers. Biodiesel enters custom as a duty free good. The latter has to face the A$0.38413 per liter excise duty but it can also enjoy the national incentive schemes and it is therefore taxed in the same proportions as biodiesel produced domestically.

3.8 Thailand

Thailand has successfully promotoed the implementation of biofuels. The introduction of gasohol (blend with 10% ethanol and 90% gasoline with octane number of 95 RON, equivalent of E10) has contributed to a significant displacement of standard gasoline. In 2006 gasohol demand increased by 83% while gasoline sales fell by 34% (Preechajarn *et al.*, 2007). At the beginning of 2008 gasohol consumption reached 10.52 million liters per day (Prasertsri and Kunasirirat, 2008), which would correspond to 3.8 billion liters per year. The growth of gasohol usage has been astonishing given that in 2004 its consumption totalled 60 million liters (Preechajarn *et al.*, 2007). Amranand (2008) expects gasohol sales to reach the target of 12 million liters per day by the end of 2008 and that in 2009 the 75% of total gasoline sales will be due to gasohol. In an attempt to further boost demand, the government is promoting the use of E20 and E85 compatible vehicles[83].

Currently the Thai government has indefinitely postponed its intention to make gasohol (E10) mandatory. Gasohol was meant to replace premium gasoline by the beginning of 2007, but concerns over insufficient ethanol supplies reversed the decision[84]. Ethanol exports are generally discouraged[85] in order to safeguard internal demand, but *ad-hoc* licenses have been issued after the non-implementation of mandatory blending in order to limit surplus output. Mandatory requirement may not be necessary to promote the ethanol based biofuels as Gasohol consumption is estimated to be 20 million liters a day by 2011 (Preechajarn *et al.*, 2007).

Biodiesel with a 2% methyl ester content (B2) has replaced standard diesel across the country in 2008. The government expects to mandate B5 biodiesel by 2011. Pure

[83]Import tariffs for E85 compatible vehicles have been slashed, as well their excise taxes. Their level will be similar to the already reduced taxes for E20. Refer to the following (as of August 2009):
http://www.aseanaffairs.com/thailand_fuel_excise_tax_govt_slashes_import_tariffs_for_green_cars
http://www.readbangkokpost.com/business/oil_and_energy/is_thailands_third_quarter_e85.php.

[84]Another element of concern was the significant share of cars on the road that still required standard gasoline.

[85]All ethanol producers are registered without export licenses (Preechajarn *et al.*, 2007).

biodiesel or B100 is also commercially available but it is of low quality (made mostly from cooked oil) and its used is recommended only in simple agricultural machines.

Armranand (2008) reports that as of June 2008 the consumption of all four alternative transport fuels (ethanol, biodiesel, CNG, LPG) totalled 6.8 million liters of crude oil equivalent per day and replaced 10.3% of gasoline and diesel demand. He further argues that "by 2020 the substitution of gasoline and diesel by biofuels, natural gas and LPG would increase from 8.1% during the first half of 2008 (equivalent to 5.8 million liters of oil) to 29% (equivalent to 34 million liters of crude oil) in 2020[86]."

Support policies are based upon taxation benefits for biofuel suppliers. Gasoline faces higher taxes compared to ethanol. In addition, the government established a benchmark ex-factory price of ethanol calculated in relation to the Brazilian ethanol price, which lowered previous price levels and helped decrease biofuels blending costs. The two instruments led to an increased differential between standard gasoline and gasohol prices of about 4 baht per liter in November 2007. Adjusted for energy content in heating values, in the first half of 2008 the ex-factory price of ethanol was 3% lower than the ex-refinery price premium gasoline (Armranand, 2008). It is arguable that the ethanol industry can start to stand on its own feet without being subsidized.

3.9 Malaysia

Malaysia's biofuel production centres around biodiesel derived from palm oil. Ethanol is not being manufactured. Malaysia and Indonesia contribute to 86% of the world's palm oil output. Malaysia is the largest exporter while Indonesia has been the largest producer since 2006.

As Lopez and Laan (2008) report, palm oil is the country's most important agricultural commodity. The cultivated area of palm trees expanded from 2 million hectares in 1990 to 4 million hectares in 2005. Palm oil output increased from 6 million tonnes in 1990 to almost 16 million tonnes in 2007.

The Malaysian government hoped to take advantage of the increasing interest in biodiesel and the country's leading position in the production of palm oil. In 2005 the **National Biofuel Policy** (BNP) was launched. A 5% biodiesel (B5) mandate was envisaged. Legislation to regulate and assist the biofuel industry was formulated by the **Biofuels Industries Act** in April 2007. As of August 2008 the act was still to be officially turned into law (Lopez and Laan, 2008)[87].

[86] Armranand (2008), p. 13.
[87] I.e. the 5% biodiesel mandate is not yet in place.

Two types of biodiesel are being produced. *Envodiesel* is obtained from the direct blending of petroleum diesel with raw palm oil. The latter is used for domestic consumption. Alternatively *palm methyl esters* (PME) biodiesel are manufactured via transesterification. PME is destined for the international markets and constitutes the largest share of biofuel production. In 2007 Malaysia exported 95 000 tonnes of PME, equivalent to around 75% of total biodiesel production (Lopez and Laan, 2008).

Neither the biodiesel industry nor the palm oil sector benefit from direct subsidies or tax exemptions. Petroleum, on the other hand, is highly subsidized. End-user prices are set by the government at lower rates compared to international prices. The total amount of fuel subsidies varied over the years: in 2006 it totalled US$4.3 billion and in 2007 it reached US$4.7 billion. The integration of biofuel shares was meant to lower the budget spent on petroleum subsidies. However, the rising costs of palm oil (also caused by increased demand for biofuels) contribute to biodiesel being more costly to produce than petroleum based diesel. Due to this reason it is likely that the government has hesitated to turn the 5% biodiesel mandate into law. Lopez and Laan (2008) estimate the potential loss incurred by the government if the B5 integration target was mandatory at US$675 millions per year.

The biofuel industry is nonetheless able to enjoy an indirect form of financial assistance. Through the large share of their output destined for exports, Malaysian companies take advantage of the subsidies in place in the EU and in the US.

3.10 Indonesia

In October 2008 mandatory levels of biofuel consumption from 2010 to 2025 were introduced in Indonesia. By 2010 the biodiesel share shall amount to 2.5% and reach the 20% mark by 2025. The ethanol component of gasoline is required to be 3% in 2010 and increase up to 15% by 2025[88] (Dillon *et al.*, 2008). The latest requirements reformulated previous governmental plans that predicted a 10% biofuels share by 2010 (Bromokusumo, 2007).

The government subsidizes fuel prices (as it is the case in Malaysia). Dillon *et al.* (2008) estimate that fuel subsidies totalled more than US$14.5 billion by October 2008. Ethanol and biodiesel blends are sold to end-consumers at the same price as standard petroleum based gasoline and diesel. Petromina, the only blender and supplier of biodiesel and ethanol is a government owned company. Therefore, the losses it incurs in order to match the mandatory biofuel share can be considered to be subsidies to the biofuel industry. Between 2006 and June 2008 the losses endured by Petromina due to biofuel blending amounted to US$ 40 million.

[88]Biodiesel targets are 2.5% in 2010, 5% in 2015, 10% in 2020 and 20% in 2020, with respective requirements of 748 million liters in 2010, 1820 million liters in 2015, 4430 million liters in 2020 and 10780 million liters in 2025. Ethanol is mandatated to meet the 3%, 5%, 10% and 15% in the same time frame with corresponding volume targets of 635, 1285, 3120 and 5696 million liters.

In 2006 Petromina started selling a blend with 5% biodiesel (B5). Over time, due to the high costs of production the biodiesel content was reduced and by May 2008 it fell to 1%. Dillon *et al.* (2008) further report that in the second half of 2008 biofuel prices began to ease again and production levels increased. Output capacity for both biodiesel and ethanol has also been expanding.

In Indonesia there are 11 commercial-scale biodiesel producers with a total production capacity of 1.6 million tonnes per year[89]. All biodiesel is produced from palm oil given the country's leading position in palm oil output, even though jathropa is hoped to play a role in the future. By 2010 biodiesel capacity is forecasted to exceed the 4 million tonnes per year. Ethanol capacity is much lower and is estimated to total 114000 tonnes in 2008. New facilities are under construction and production capacity should exceed the 3 million tonnes by 2010. Sugarcane and cassava are the feedstock of choice.

Direct support of the biofuel industry is granted through the mandatory blending quotas and subsidies to fuel (and hence also biofuel) prices. The losses incurred by providing biofuels at lower prices are sustained by a government owned subsidiary and can be considered as direct subsidies. There exist other minor policies that provide assistance to biofuel production, though only indirectly (i.e. fertilizers subsidies, conversion of land for biofuel plantations, interest-rate advantages on loans for farmers), and exemption from the 10% VAT (but the latter is included in the losses endured by the governmental company). Another important element for indirect financial aid is given by support policies of the importing countries such as the US and the EU as discussed in the case of Malaysia.

3.11 Japan

The Japanese government plans to substitute the equivalent of 500 million liters of crude oil with biofuels by 2010. This target complies with the **Kyoto Protocol**, which commits Japan to a 6% reduction of CO2 emissions with respect to the 1990s levels within the 2008-2012 period (Fukuda *et al.*, 2006). In an attempt to curb the use of oil in the transport sector, the **New National Energy Strategy** of 2006 ultimately sets a goal of 6 billion liters in ethanol production by 2030, which is equivalent to around 10% of current gasoline consumption (Masaki, 2007)

In 2002 the **Biomass Nippon Strategy** incentivized the use of biomass as a source of renewable energy and provided financial funds to several ministries and departments. The first stage of the Kyoto Protocol, originally signed in 1997, began its first implementation phase in 2005. The Ministry of Economy, Trade and Industry (METI) presented in 2006 the New National Energy Strategy, which aimed at curbing Japan's dependence on oil for transport and envisaged a reduction in the use of oil for transport from 100% to 80% by 2030 (Masaki, 2007).

[89] As of November 2008

Japan's goals are very ambitious. The country is a net importer of agricultural commodities and 60% of its food consumption is produced abroad. Land is a scarce resource. Biodiesel is still at an infancy state and most of its fuel ethanol is being imported from Brazil and China. In order to meet the envisaged target of 500 million liters of crude oil equivalent, the petroleum industry plans to blend gasoline with 360 million liters of Ethyl Tert-Butyl Ether (ETBE), which corresponds to 210 million liters of crude oil. The remaining 290 million liters of crude oil equivalent should come from ethanol blending (JPEC, 2008).

The distribution of ethanol blended with gasoline has started in 2007 and plans to reach the 1000 outlets by the end of 2009 fiscal year. Ethanol content made available is relatively low at 3%, with a remaining 7% mixture of ETBE.

According to Masaki (2007) the government also plans to mass-produce cellulosic ethanol by 2015 and substantially decrease its manufacturing costs as well as provide fiscal incentives. It is expected that biofuels will be exempted from fuel excise duties and that the current 3.1% *ad valorem* import tax on ETBE will be eliminated. Fukada *et al.* (2006) also report that the *ad valorem* import tax on ethanol will be constantly decreased until it will reach the 10% mark in 2010.

3.12 South Korea

South Korea's policy on biofuels focuses on biodiesel. The government set an integration target of 0.5% of biodiesel by 2007, 2% by 2010 and 3% by 2012[90] (Choi and Francom, 2008). The increase in the use of renewable energy sources follows concerns over Korea's high GHG emissions and severe air pollution, the latter being one of the worst among OECD countries (Phillips and Choi).

More than 30% of the 16 million vehicles in the country are diesel powered and diesel consumption is twice as large as that of gasoline. Seoul's highly congested traffic contributes to levels of air pollution comparable to those of Mexico City. In addition, Korea is characterized by heavy industries, which make it one of the top ten GHG producers in the world (Phillips and Choi, 2006).

The Ministry of Knowledge and Economy (MKE) has increased the biofuel targets and committed to a higher share of energy coming from renewable sources in an attempt to improve GHG emissions and air pollution. In September 2008 it was announced that the share of total energy consumption coming from renewables had to increase from the current 2% to 4% by 2012 and 12% by 2030 (Choi and Francom, 2008)

[90] A biodiesel blend ratio of 0.5% in 2007 corresponds to 90 million liters, the 2010 2% target shall be met with a production of 360 million liters. In 2012 the 2% share is expected to correspond to 540 million liters.

Biodiesel distribution was started in 2006 and by 2008 it was available in most service station. The most commonly produced blend, called BD-5, contains 1% of biodiesel. Production has been increasing over time and output capacity is ready to meet the future targets. As of July 2007, Korea's biodiesel producers had an annual capacity of 667 million liters, which is already in excess of the 540 million liters required to meet the 2012 goal[91]

The vast majority of feedstock is imported. Soybean oil accounts for 80% of biodiesel manufacture it is primaly imported from Argentina. Imported palm oil and recycled cooking oil contribute to the remaining 20% of production. In order to limit feedstock import dependencies, Korean companies invested in plantations and factories in South East Asia (Choi and Francom, 2008).

Taxes account for 50% of diesel fuel prices and include a traffic tax, mileage tax, education tax and VAT. Biodiesel, on the other hand, is charged only with the VAT, though it sells at the same price as normal diesel at the pump due to higher costs of manufacture (Francom and Choi, 2007).

Bioethanol is not yet commercially available, but in 2006 the Korean government initiated a feasibility study together with the Korea Institute of Petroleum Quality (KIPEQ) in order to assess the viability of E3 and E5 blends.

3.13 South Africa

In December 2007 the South African government approved the **Biofuel Industrial Strategy**[92] proposed by the Department of Minerals and Energy. The first phase of the strategy lasts from 2008 to 2013 and it is considered a pilot stage. By 2013 a biofuel production target of 2% (equivalent to 400 million liters per annum) is expected. Blending target recommendations propose an 8% integration of ethanol and a 2% share of biodiesel. During this "incubation phase" mandatory blending is not endorsed. Ethanol shall be derived from sugar beet and sugar cane. Soybean, canola and sunflower are the feedstock of choice for biodiesel manufacture.

The final document was different from the draft released by the cabinet for consultation in 2006. Originally the biofuel integration target was meant to be 4.5% of total petrol consumption for transport. In addition, corn was excluded from the endorsed biofuel crops. The modifications implemented in the original proposal were justified by concerns over food security and rising food prices. Corn producers were surprised by the amendments and heavily criticised the government's decision (Sindelar, 2007). They were involved with the inception of a biofuel industry from its very beginning and hoped to find alternative uses for corn surpluses given a "fairly stagnant" domestic market.

[91] Source: Ministry of Knowledge and Economy (MKE), as reported by Choi and Francom (2008).
[92] Available at *http://www.dme.gov.za/pdfs/energy/renewable/biofuels_indus_strat.pdf(2).pdf*

The Biofuel Industrial Strategy specifies details on productive and financial means. Land allocation necessary to meet the envisaged target should account for 1.4% of arable land. Given that 14% of total arable land is currently underutilized biofuel production should not be constrained by lack of cultivable surfaces. Water may on the other hand be in competition for alternative end-uses. The production of second generation biofuels shall also be developed and it will benefit from the structures developed within the pilot phase.

Direct financial benefits are granted via fuel tax levy exemptions. Ethanol enjoys a 100% fuel tax exemption while biodiesel is allowed a 50% reduction. Ethanol is therefore allowed an effective support of R1.21 per liter[93]. Given that diesel's fuel tax amounts to R1.03, biodiesel profits from a R0.53 subsidy. Reductions in fuel levy are significant, since the latter constitute 27% of the petrol and 25% of the diesel price (Germishuis, 2006). Import tariffs amount to 317 Rcents per liter for undenatured ethyl alcohol (ethanol) and to 0.183 Rcents per liter for biodiesel (to which the diesel fuel levy has to be added). Exports from SADC[94] countries incur no import duties nor fuel levies. Imports of undenatured ethyl alcohol from EU countries face a slightly lower duty compared to the general rule at 237.75 Rcents per liter (Germishuis, 2006).

[93]Between April and August 2009 the Euro/South African Rand exchange rate oscillated between 12.5 and 10.8

[94]South African Development Community (SADC).

4 Economic Modelling of Biofuels

An assessment of the current support policies to the emerging biofuel industry should be based on an adequate understanding of the mechanisms underpinning the biodiesel and bioethanol production structure as well as its interrelation with other commodity markets.

Simple economic arguments have been employed to justify governmental aid: biofuels provide an alternative to oil, which is becoming increasingly more expensive. In addition, they are domestically produced and contribute to raise farmers' income. Detractors argue that biofuels are a resource intensive commodity that may harm the environment and hurt consumers indirectly through the reallocation of land, water and energy causing other goods to become more expensive. In particular, rising food prices have been related to the indiscriminate funding of bioethanol and biodiesel.

Specific aspects of the biofuels industry are evaluated by different modelling frameworks, which can be grouped in four broad categories as done by Rajagopal and Zilberman (2007). **Cost accounting models** determine the profitability of specific production patterns of a single price-taking agent. Usually they compare the economic potential of competing crops or different production regions. For instance Khanna *et al.* (2007) evaluate the cost structure of ethanol production in Illinois based on Miscanthus. **Micro-models of resources allocation and decision making** evaluate the choices made by producers and consumers in a specific market. Khanna and Zilberman (1996) use this approach to explain how the large scale adoption of precision technologies may be hindered by distortionary regulatory policies. Relevant models usually focus on the adoption of a particular crop and the investment in a given manufacturing facility for the supply side, while consumers have the possibility to use either oil or bioethanol as well as purchase flexi-fuel vehicles. **Sector models (or partial equilibrium models)** assess the impact of policies by considering single markets or industries and examining how they may be shaped by governmental targets such as biofuel mandates or tax incentives. Usually each model refers to a specific industry in a nation-wide or global context and may also take into account some sectors that are mostly affected by the policies under scrutiny. Finally, **general equilibrium models** are the most comprehensive tool available to analyse governmental intervention at the aggregate level. Each sector of the economy is represented by specific production structures that share given resources. Governments are limited in their budgets by the amount of taxes they can raise. Consumers earn their income by providing labour and capital to firms. Consumption is determined by the constraints of factor income, agents' preferences and the commodity prices, which are in turn established by the market clearing equilibrium. In most cases such models include several countries and account for international trade. Usually they are formulated as **computable general equilibrium (CGE)** models, which allow for numerical solutions of the complex non-linear system of equations that characterize them.

The objective of this work is to evaluate the consequences of promoting renewable energy on the German agricultural sector. The model should adequately take into account the interdependence of different sectors in order to assess how certain segments of the economy may be altered by policies that do not act directly on them. An analysis of aggregate behaviour often necessitates micro-foundations. Hence, the importance of cost accounting models and micromodels of resources allocation is not to be dismissed. However, the focus shall remain on partial and general equilibrium models.

There is a growing body of literature assessing biofuel policies via partial equilibrium or CGE models. Reilly and Paltsev (2008), Dixon *et al.* (2007) and McDonald *et al.* (2006) study the impact of bio-energy production on the US economy. Elobeid and Tokgoz (2006) focus on trade distortion in the American market, while Fabiosa *et al.* (2008) assess US land allocation effects caused by higher ethanol consumption. Arndt (2008) assesses biofuels, proverty and growth in Mozambique. Miles (2008) analyses the relationship between food production, biomass exports and land use in Argentina.

Several authors evaluate the end results of current EU policies. Banse *et al.* (2008b) and Banse and Grethe (2008) simulate the impact of European blending mandates on the global agricultural markets. Gohin and Moschini (2007) consider the implications for the EU farm sector and trade patterns. Tokgoz (2009) study the relationship between crude oil prices and the EU agricultural market. Link *et al.* (2008) evaluate the potential for domestic biofuel production and the likely changes in the domestic farm sector.

Other studies estimate the impact of biomass polices on the aggregate world markets (i.e. Banse *et al.* (2008a), Birur *et al.* (2007), Stillman *et al.* (2008), Hertel *et al.* (2008)). Taheripour *et al.* (2009) and Hayes *et al.* (2009) pay particular attention to the livestock sector. Birur *et al.* integrate their analysis with a detailed land description by using the Agro-Ecological Zones (AEZ) framework developed by Lee (2005). Taheripour *et al.* emphasize the importance of including biofuel by-products such as Distillers Dried Grains with Solubles (DDGS) in the model.

The framework of choice must adequately describe the fundamental characteristics of biofuels production that constitute a link with other industrial sectors. In order for the model to encompass the implications of ethanol and biodiesel manufacture, the following elements are usually included.

Land is a resource available in fixed supply whose allocation can be destined for forestry, pasture or crops. If biofuels are to replace a large portion of current oil consumption, extended land surfaces will have to be devoted to the cultivation of biofuel feedstock. Competition for land allocation may alter current dynamics in the agricultural sector and it will put upward pressure on prices. Potentially pasture or even forestry areas may be converted in order to cultivate energy crops once demand for biofuels is sufficiently high. The envisaged adoption of second generation technologies may reduce but not eliminate competition for land. The mechanisms decribing soil allocation and conversion are therefore a crucial component in the assessment of biofuel policies.

Food supply is a central issue associated with the enlargement of a global biofuel industry. Food is affected in several ways. Agricultural commodities such as corn, sugar cane, sugar beet and vegetable oils are already being directly reallocated toward the manufacture of ethanol and biodiesel. An increment in the production of biofuel crops may lead to a reduction in land cultivated for alimentary provisions. A decline in land destined for food production implies a lower supply, which would cause higher prices (under the assumption of constant demand). In addition, increases in the costs of the energy, labour and water inputs may be transmitted to food prices and production.

Labour is another key component that distinguishes the agricultural sector. The latter is characterized by lower income levels compared to other industries. Biofuels are considered a labour intensive commodity, so that an expansion of the biofuels industry would create new jobs, potentially reallocating a share of the existing ones and perhaps contributing to a reduction in the income differential.

Energy modelling is a further key issue. Biofuels consume energy during their production phase and supply energy once they are ready for available for distribution. If they are to replace a significant share of the world's oil consumption, it is important to consider the repercussions on other industry segments that contribute to the world energy supply other than oil such as coal, natural gas and electricity.

Demand for **transport** and the current inability to substitute away from liquid fuels is driving biofuels production. The total displacement of oil consumption will inevitably depend on the number of cars that can run on ethanol or biodiesel high blends as well as on improved distribution and retail of biofuels.

The next section presents an overview of recent modelling approaches estimating the aggregate impact of biofuels and their support policies. Partial equilibrium models are discussed first. Computable General Equilibrium models are introduced thereafter.

4.1 Partial Equilibrium Models

Sector models examine the response of aggregate functions but limit the scope of their analysis to a selected part of the economy (i.e. the agricultural market in the US, the relationship between biofuels and food-crops, etc.). Their framework considers only those individual markets whose interaction is under scrutiny. *De facto* partial equilibrium assumes that the excluded markets are indifferent to or have no feedback-effects on the variables included in the model. Theoretically all complements and substitutes whose prices can change should be represented in the model. Usually micro foundations of agents' and producers' behaviour are included and determine aggregate demand and supply of production factors, commodities and consumption. Depending upon the structure of the model, a variety of elements may be considered endogenous. Equilibrium is found through a static or dynamic process where prices adjust until supply and demand come to match each other.

An overview of the most relevant sector models and their contribution toward the study of biofuels and biomass is given next. It must be noted that biofuels are generally analysed within structures dedicated to the study of agriculture in order to better capture the effects of an expanding biofuel industry on food supply and land allocation. Partial equilibrium frameworks that have a global dimension (AGLINK-COSIMO, IMPACT) are described first, followed by models that focus on Europe (ESIM, CAPRI) and the US (FAPRI).

4.1.1 AGLINK-COSIMO

The AGLINK-COSIMO framework is a partial equilibrium model of world agriculture developed by the OECD and the FAO for medium-term forecasts. Non-agricultural commodities are excluded and treated as exogenous. About 60 regions and 40 products are covered through 1500 equations. The most important commodities enjoy a complete representation of supply, demand, trade and prices. The equilibrium results are generated through a recursive dynamic structure allowing for an adjustment path from the base year to the final simulation year (Adenäuer, 2008). Competition for land among crops occurs through cross-price effects linking growing surface areas and crop revenue. Crop production is the product of area harvested and yield per hectare. Area harvested and yield per hectare can be separately affected by relative prices and governmental policies (OECD, 2007).

In 2008 the AGLINK-COSIMO model has been extended to include a representation of the biofuel market for the 20 regions representing 94% of global fuel ethanol production and 81% of the world biodiesel production. Biofuel prices and trade are endogenously determined, while the relevant support policies of the included countries are also incorporated in the framework. The most recent applications of the AGLINK-COSIMO models are illustrated in the OECD/FAO's *Agricultural Outlook 2008-2017*[95] as well as in the OECD's *Biofuel Support Policies, An Economic Assessment*[96].

In the *Agricultural Outlook 2008-2017* biofuels are expected to double in production. World average prices of bioethanol and biodiesel are expected to rise and settle at a relatively stable value (see Figure 1 and Figure 2 in Section 2). International trade remains limited as production is mostly destined for national consumption. Food prices also increase considerably and are expected to remain at higher average levels over the medium term compared to the previous decade.

[95] See OECD/FAO (2008)
[96] See OECD (2008)

The OECD's *Biofuel Support Policies* provides a more in depth description of the biofuel modelling structure employed in the AGLINK-COSIMO framework. The production chain of fuel ethanol and biodiesel is represented in detail. The model includes investment decisions for increasing output capacities, limited flexibility in feedstock use and by-products of grain-based ethanol that can be used in the livestock industry. Second generation technologies for ethanol and biodiesel production are also expressed by cellulosic-ethanol and BTL respectively, though their manufacturing chain has a less detailed construction.

Output capacity growth depends on the net revenues from biofuels production, but adjustments occur after several time lags. On the other hand, capacity use responds immediately to the level of net revenues and market signals. Market signals in turn are related to biofuels demand. Ethanol's demand is divided into three separate components[97] that interact with the price ratio between ethanol and gasoline. Biodiesel demand has a simpler structure and is a function of the price differential between biodiesel and fossil fuel. The Stylized Agri-environmental Policy Impact Model (SAPIM) is linked with the changes occurring in the agricultural sectors of the AGLINK-COSIMO framework in order to evaluate the environmental impact of the biofuel policies.

The study concludes that current policies provide sufficient incentives for further growth in the biofuel industry, potentially having important implications for global land use and causing an expansion of land used for crops particularly in Latin America and Africa. In addition, the results show that agricultural markets have become more sensitive to energy prices.

4.1.2 IMPACT

The International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) developed by the International Food Policy Research Institute (IFPRI) is a model for projections of global food demand, supply and trade. It covers 36 countries and regions. IMPACT includes 16 commodities representing a variety of crops and livestock. Demand, supply and prices of agricultural products are derived within each country or regional sub-models and based on a system of non-linear equations and elasticities. Countries and regions are linked via trade. World prices are determined annually such that international markets clear. Local demand for individual products depends upon price, income and population growth. Growth in crop production is related to crop prices and the exogenously determined rate of productivity growth. Food security in developing countries is also estimated by projecting the percentage and number of malnourished preschool children (0 to 5 years old). All simulations use 1997 as the base year (Rosegrant *et al.*, 2001).

[97] An additive component where ethanol substitutes alternative chemicals mixed with gasoline; a segment where the low-level energy content of ethanol is offset by superior other qualities; a component where ethanol demand is contingent on the level of flex-fuel vehicles available.

Msangi et al. (2006) employ the IMPACT model to evaluate the potential consequences of increased biofuel production. The framework adopted by Rosengrant *et al.*(2001) is expanded to include biofuels output and reflect increased utilization of maize, sugarcane or other crop feedstock. The levels of ethanol and biodiesel production are calculated on the basis of official government plans and estimates of fuel demand in the transport sector. For countries that do not provide future fuel displacement, Msangi *et al.* (2006) assume high substitution ratios of 10% by 2010, 15% by 2015 and 20% by 2020 in order to simulate "upper bound" impacts. No growth of biodiesel is assumed for countries outside of the EU. The model then estimates three alternative scenarios. If no technological and productivity advancements take place, then prices are expected to rise significantly and children malnutrition increases substantially. The inclusion of cellulosic ethanol production and high productivity rates softens these effects, though food prices would still increase.

4.1.3 ESIM

ESIM[98] stands for European Simulation Model. It is a comparative-static partial equilibrium model that describes demand, supply and trade of 37 agricultural commodities. Each EU member state, Turkey (a potential EU member state) and the US are modelled as individual countries, while the rest of the world is aggregated as a single unit. ESIM is conceived to replicate the evolution of European agricultural markets. The EU's policies and instruments such as ad-valorem tariffs, quotas, threshold prices, subsidies and direct payments are modelled in detail. Production and consumption in the rest of the world take place at world market prices.

Supply for all crops, animal products, pasture and voluntary set aside is defined at the farm level. Processing demand and human demand are associated with different goods and in some cases they are in competition with each other. The price transmission between domestic and import prices is given by a logistic functional form. Behavioural parameters are represented by the elasticities of the isoelastic demand and supply functions. The elasticities are exogenous parameters either automatically generated by GAMS algorithms or defined by the users of the model for key values.

Banse and Grethe (2008) extend the ESIM model to account for production and demand of fuel ethanol and biodiesel in order to assess the impact of the new EU biofuels directive on European land use and agricultural markets. The production of biofuel crops is modelled by a single isoelastic yield function and two isoelastic area allocation functions. The latter refer to fuel crop production either on non-set aside land or on set-aside land. Set-aside area for biofuels is allocated according to a function of input

[98]There exist different versions of ESIM. The original version was programmed in SuperCalc by the US Department of Agriculture (USDA). In Europe the original platform was further altered. More recently, ESIM was made available in the programming language GAMS. There exist differences across the versions of ESIM associated with SuperCalc or GAMS. Here all references are to ESIM in GAMS as described by Bamse, Grethe and Nolte (2004).

prices, direct payments, and output prices of biofuel crops. The equivalent function for non-set aside land considers all crops and special energy crop premium. The payment of 45 €/ha on non-set aside is modelled as a biofuel subsidy.

Two scenarios are proposed: one where 6.9% of all transport fuels in the EU are displaced by biodiesel and bioethanol by 2020. Alternatively, the proposed European directive of 10% displacement by 2020 is modelled. In both cases the envisaged goals have to be met through higher net imports of biofuel, ethanol and their input feedstock. The simulations indicate that biofuels consumption expands more than their domestic production. Oilseeds and plant oils experience substantial increments in prices (on average above 7% of the baseline scenario in 2020). Plant products, sugar and to a smaller extent wheat prices increase. More generally, crop prices in the EU and world markets are expected to rise.

4.1.4 CAPRI

The Common Agricultural Policy Regionalized Impact (CAPRI) model is a "spatial" partial comparative static economic platform that has been developed within the EU to analyze the evolution of its agricultural markets. The framework is characterized by a detailed representation of European agriculture and focuses on EU policies with a special attention to the promotion of CAP schemes. Each member state of the EU27, Norway and Western Balkans are endowed with aggregate non-linear programming models in the form of Nomenclature of Territorial Units for Statistics at level 2 (NUTS II). The latter capture detailed farming decisions of regional supply. The model is able to replicate CAP and trade policy instruments and include different energy and environmental indicators. The European supply is then integrated in a global multi agricultural commodity spatial market module based upon the Armington approach. In total 28 trading blocks area included as well as 46 commodities. Behavioural parameters are exogenously taken from relevant literature (DG AGRI, ESIM, FAO) but are calibrated to ensure consistency (Adenäuer, 2008).

There is an ongoing attempt to modify CAPRI in order to evaluate the impact of the EU's biofuel targets[99]. The objective is to include a model for European biofuel supply and global biofuel trade. A link with the PRIMES model would ensure endogenous biofuel demand (Becker and Adenäuer, 2009; Becker, 2008)[100].

In addition, the Joint Research Centre (JRC) of the European Commission together with the University of Bonn have linked the DeNitrification-DeComposition (DNDC)

[99] IPTS/DG-JRC, Project No J05/32/2008, *Integrated Impact Assessment of an Increse in Biofuel Demand in Europe: The Economic and Technological Dimension.* The project is undertaken by the Institute for Agricultural Policy at the University Bonn and the Institute of Communication and Computer Science (ICCS) in Athens. See *http://www.ilr1.uni-bonn.de/agpo/rsrch/projects/ipts_biofuel_e.htm*

[100] Also notice the EU-LIFE project "EC4MACS", where CAPRI and the energy model PRIMES are linked.

model with the CAPRI framework (Britz and Leip, 2009; Britz and Leip, 2008; Leip *et al.*, 2008). The DNDC assesses carbon and nitrogen biogeochemistry in agro-systems. Its application help to better estimate the environmental consequences of increased cultivation of energy crops through a detailed analysis of potential leads and fertilizer application, nitrogen leaching and emissions of trace gases such as nitrous oxide (N20), nitric oxide (NO), dinitrogen (N2), ammonia (NH3), methane (CH4) and carbon dioxide (CO2).

4.1.5 FAPRI

The Food and Agricultural Policy Research Institute (FAPRI) model is a multi-commodity and multi-country partial equilibrium structure built by the Iowa State University and the University of Missouri-Columbia. US agricultural commodities are described in detail and US governmental policies are regularly integrated and updated in the framework. Econometric and simulation sub-models of all major crops, livestock and meat products are included for the most important producing and consuming countries. Due to the large scope of the model, FAPRI is regularly used to simulate projections in the US and the world. There exist several versions of FAPRI, though the most extensive formulation is the basic international FAPRI framework adopted for outlook market analyses (FAPRI, 2007)[101].

Fuel ethanol and biodiesel are also included in the system. The ethanol sub-sector is a multi-market non-spatial world model. Linkages with feedstock crops, world sugar and gasoline markets are included. Consumption and production are expressed in detail for the US, Brazil, the EU-25, China and India. Trade equations are also linked to Japan and South Korea and the Rest of the World as an aggregate. Country production is distinguished by the type of inputs and processing technique used (i.e. corn from dry-milling with dried distillers grains in the US). First a world ethanol price is solved through a non-excess demand condition. Domestic prices are associated to the world price via exchange rates and various policy parameters. Biodiesel is described in a similar but less detailed manner. Competition for land occurs among crops grown within given geographical areas and depends on the revenue associated with agricultural prices and supply. Crops supply in turn is contingent on harvested surface multiplied by yield ratios.

Fabiosa *et al.* (2008) employ FAPRI to estimate the land allocation effects of increased ethanol production. The simulation results show that in the US land for major crops and prasture is displaced in favour of energy crops while ethanol output expands. The reduced supply of coarse grains and consequent increase in prices has global effects on land allocation. Similar but considerably smaller impacts are caused by production expansion of Brazilian sugar-based ethanol. In June 2008 the University of Missouri

[101] These include the FAPRI Crop Insurance Model, the FAPRI Internationl Dairy Model, the FAPRI Internationl Grain Model, etc. Recently a stochastic version has been implemented by the University of Missouri-Columbia.

released a report on the impact of selected US farm and biofuel policies (FAPRI-MU, 2008) based on the stochastic version of FAPRI. The analysis highlights that recent trends in energy and agricultural markets are very sensitive to alternative scenarios and market circumstances.

4.2 General Equilibrium Models

General equilibrium models describe all sectors, international trade and governmental policies that constitute a global economy. They account for all feedback effects a shock in a given sector of the economy may induce in other industries. Due to their complexity, they are solved via the use of computer generated solutions, hence the name Computable General Equilibrium (CGE).

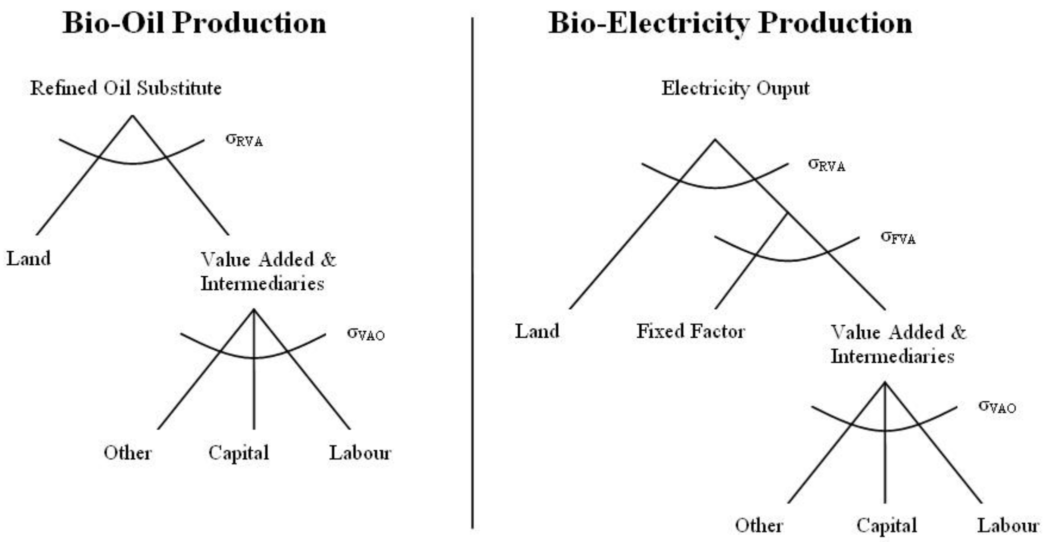
There is an increasing number of CGE models assessing the impact of biomass on the energy markets, its repercussions on food commodities and the allocation of land. Two distinct approaches have been taken. The first one simulates the impact of the current bio-transformation techniques and implements them to a larger scale. It considers products that are already commercially viable (i.e. biofuels from corn or sugar). It does not make conjectures on the future outlook of the industry but it focuses on the current status of the economy to infer probable developments (Banse *et al.* (2007); Birur, Hertel and Tyner (2008)).

Yet the bio-energy industry is still in its infancy and the aforementioned models may misestimate the resources available through biomass. A second approach tries to encapsulate the potential of bio-energy in more general terms. It incorporates in the models production techniques that are not yet commercially viable (i.e. second generations biofuels from woody crops), or it tries to estimate the energy content that can be derived from cultivated land, without necessarily specifying a processing technique (see Reilly and Paltsev (2008)).

The choice of either approach is crucial and determines the conclusions that can be derived from results. In either case, the outcomes of CGE's simulations are contingent on the model structure, which underlies an ad-hoc representation of economic and technological relationships. An evaluation and comparison of alternative approaches is fundamental. A clear understanding of how the model-specific economy representation leads to different scenarios is necessary. This is a first and crucial step to gain greater awareness of the advantages and drawbacks encompassed by each model. The reliability and scope of the results follow from the premises that lie beneath the simulation dynamics.

4.2.1 The EPPA Model

Reilly and Paltsev (2008) integrate biomass production technologies into the MIT Emission Prediction and Policy Analysis (EPPA) model. Their goal is to determine the poten-



Source: Reilly and Paltsev (2008)

Figure 5: Bio-Oil Production and Bio-Electricity Production in EPPA Model

tial contribution of land cultivation toward biomass energy supply in the most general terms possible. They specify a general production function for bio-oil and bio-electricity because "a more detailed nest and input structure would entail describing in greater detail a technology that is not fully developed and is likely to change considerably as technology advances[102]."

EPPA is a recursive multi-regional computable general equilibrium model based on the GTAP data set. The world is aggregated in 16 regions and 21 sectors. The base year is 1997. In order to tackle the specific technologies employed for the conversion of biomass into energy, the authors include bottom-up engineering production details. Biomass is expected to originate liquid fuels and electricity. The structure of biotechnology production functions is represented in Figure 5.

Bio-electricity and bio-oil use land and a combination of labour, capital and other inputs. Land is assumed to be a non-depletable resource with exogenously augmented productivity. The rate of land productivity varies across regions and over time with a generally upwards trend in order to include the historical increment in crop yields as well as differences in productivity across the world due to different technological advances available.

[102]p.10, Reilly and Paltsev (2008).

Finally, a set of mark-ups and input shares for the bio-products is assigned. This measure is meant to describe multipliers that determine when the bio-technologies will be competitive in the market. A mark up of 2.1 means that bio-oil will be competitive when refined oil prices are 2.1 times higher compared to their 1997 value (assuming no changes in the price of inputs for either product).

Land use is modelled as a homogeneous input. Thus, land is perfectly mobile among the three sectors that make use of it: an aggregate agriculture sector that includes all crops, livestock, and forestry production; biofuel liquids; electricity from biofuels. Variation in land price and quality are eliminated by expressing land hectares as an "average cropland equivalent." Since land inputs must be measured through a price, the latter's derivation is rather elaborate. It is assumed that the energy yield from biomass averages around 300 GJ/ha/year as a projection of technical potential. In order to estimate the initial value share of land in biofuel production, the average USA cropland price is combined with the 40% efficiency of energy conversion for the assumed yield of 300 GJ/ha/year.

The analysis focuses on the potential of biomass resources and land allocation. The model provides a general account of how much land is needed for bio-energy provisions under a variety of scenarios. As land is subtracted away from aggregated agricultural uses, the outlook of an economy is altered. Reilly and Paltsev (2008) centre their attention primarily on the US and the impact of US GHG emission policies. The authors conclude that "the scale of energy use in the USA and the world relative to biomass potential is so large that a biofuel industry that was supplying a large share of liquid fuel demand would have very significant effects on land use and conventional agricultural markets[103]." In particular, the United States could become net importers of food compared to today's net exporter status.

The main limitation of this modelling approach is pointed out directly by Reilly and Paltsev. In CGE data, the value of different types of land corresponds to different marginal productivities. A monetary "average cropland equivalent" may put together more hectares of less productive land or fewer hectares of more productive soil. The misrepresentation of the model is implicit: it makes productivity of land with respect to GJ/ha/year directly proportional to land price.

A second drawback may be the aggregation of the agricultural sector to encompass all crops, livestock and forestry production, which prevents a more detailed analysis of the effects of biomass energy on alimentary products. An alternative decomposition of commodities is necessary if one wants to estimate the impact of bio-energy on food commodities. Corn and sugar are the main biofuel feedstock and face considerably different production dynamics compared to forestry. Not every crop is suitable for bio-energy production and their land requirements also change significantly. Moreover, land itself

[103]p. 2, Reilly and Paltsev (2008).

enjoys unique regional characteristics that may be better suited for a particular cultivation. The measure of "average cropland equivalent" fails to spot the diversity associated with specific crop requirements.

4.2.2 GTAP-AEZ

In order to accurately describe the fixed land supply available in the world, the modelling of land use in the GTAP framework has undergone substantial improvements over the past few years. In particular, Agro-Ecological Zones (AEZ) have been introduced. Following the conventions developed by FAO and IIASA, the world is divided into three climatic areas: Boreal, Continental and Tropical. Within each climatic area there are six further zones ranked according to the "length of the growing period" (LGP) for which climate characteristics can support crop growing[104].

That is, AEZ1 covers a land of temperature and moisture regime that is able to support an LGP of up to 60 days per annum. AEZ2, on the other hand, can support an LGP between 61 and 120 days per annum, and so on. The world in general and each specific country is subdivided in zones that belong to any of the 18 AEZs (see Fischer *et al.*, 2002 and FAO, 2000). Zones in a given AEZ have similar soil, landform and climate characteristics.

There are extensive databases that match this modelling approach. The Center for Sustainability and Global Environment (SAGE) provides the data for land acreage and production thanks to Ramancutty. SAGE supplies detailed information on 19 crops, which are then matched to the 8 crop subgroups used in GTAP. Sohngen of Ohio State University contributes to the database for forest land[105]. These records are then calibrated so to be added to the existing structure of the GTAP-E model developed by Burniaux and Troung (2002).

The greater detail provided by the GTAP-AEZ land description can be implemented in a variety of ways. Lee (2005) specifies that land is mobile between crop, livestock, and forestry sectors *within, but not across*, AEZ's. The same product, say paddy rice, may have different productivity levels depending on the AEZ on which it is cultivated. On one hand, all paddy rice sectors across the six AEZs produce the same end product. However, the paddy rice produced in AEZ1 is modelled so to have a different production function from the same crop cultivated in AEZ4. As Ramankuttty, Hertel and Lee (2005) put it, if two products never appear in the same AEZ, they will never compete for land against each other. Substitutability across land uses is measured by a constant elasticity of substitution for products in the same Agro-Ecological Zone. GTAP-AEZ

[104] As stated by Lee (2005), p. 5, "in a formal sense, LGP refers to the number of days withi the period of temperatures above 5C when moisture conditions are considered adequate (FAO, 2000)."

[105] Lee (2005) does not refer to specific publications of either Ramankutty or Sohngen. Ramankutty, Hertel and Lee (2005) indicate a series of papers in relation to the SAGE global land use data later adopted by GTAP-AEZ.

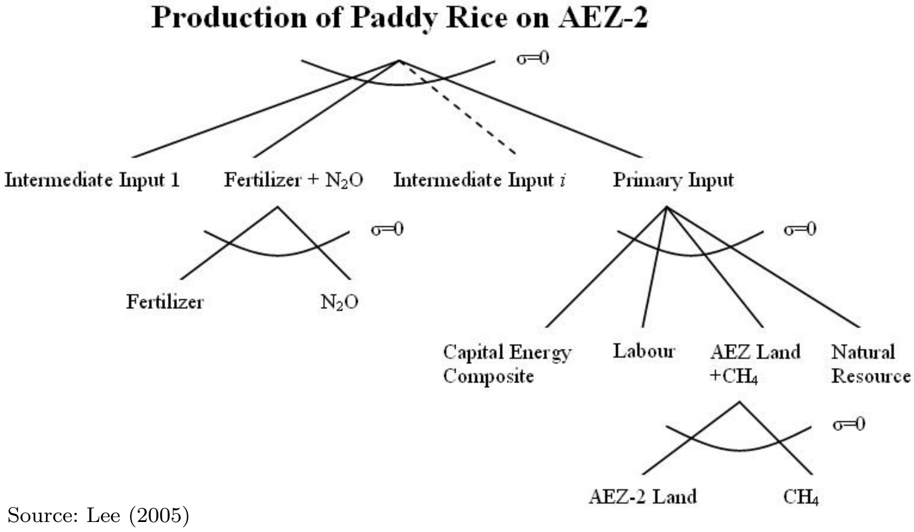


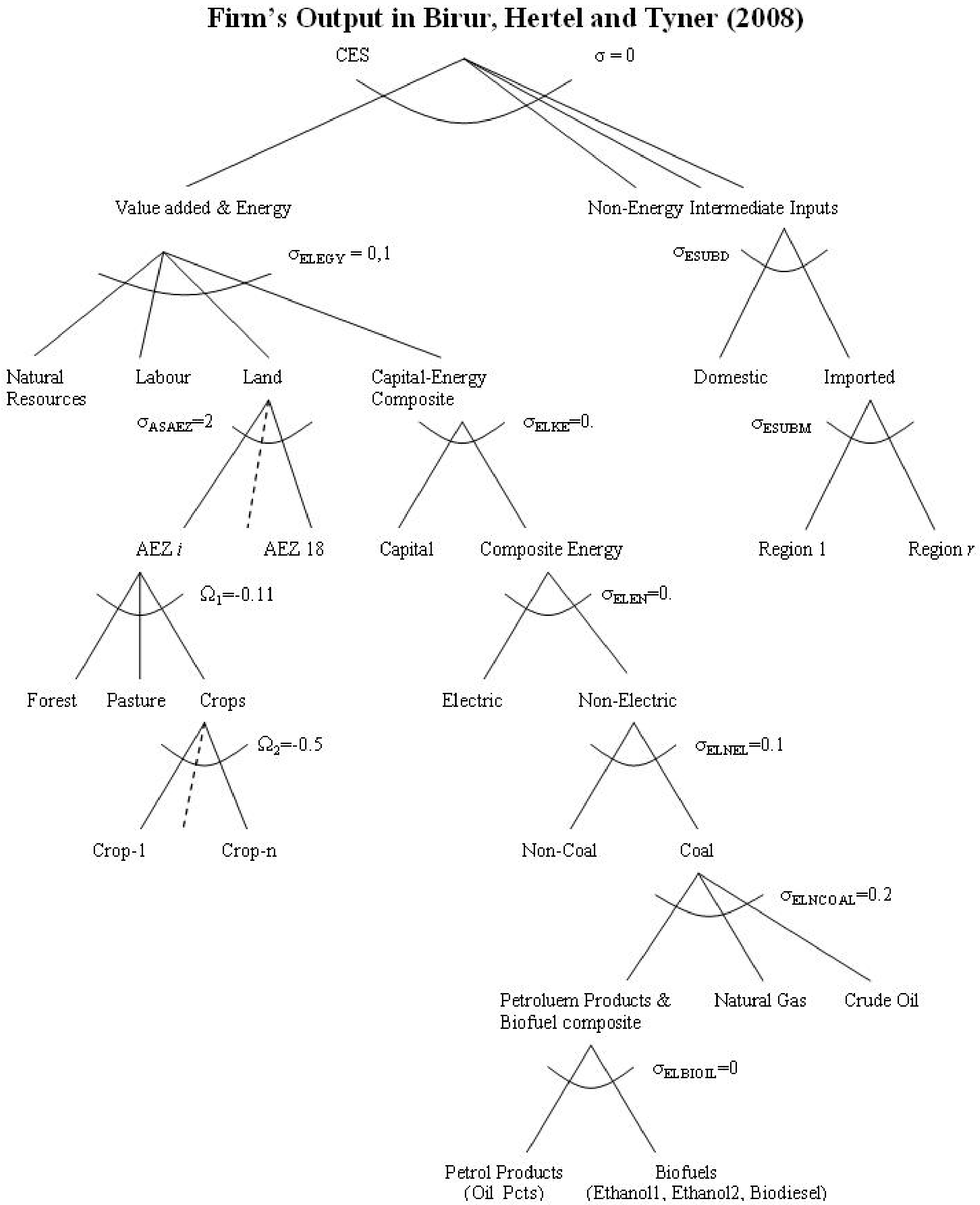
Figure 6: Production of Paddy Rice on AEZ-2

is further augmented to consider the impact that land usage may have on the GHG emissions. In line with GTAP-L originally developed by Burniax (see Burniaux, 2002), specific cultivations are associated with emission of methane (CH4) and Nitrous Oxide (N20) depending on the land type required (Figure 6). The detailed land description provides a useful platform to assess the impact of changes in land allocation due to biofuel production.

4.2.3 Biofuels and GTAP-AEZ

Birur, Hertel and Tyner (2008) build on the GTAP-E framework by Burniaux and Truong (2002) and the GTAP-AEZ land description with additions to the biofuel component of supply and demand. They employ the AEZ land database but do not ascribe a specific production function for each good manufactured in a given AEZ region as done by Lee (2005). Within a given AEZ, land mobility is limited across alternative uses (crops, pasture or forestry), which are divided in two tears (see Figure 7). Land allocation ultimately depends on a Constant Elasticity of Transformation (CET) frontier. Revenue from land is maximized by selecting the optimal combination of crops, pasture and forest.

Three new types of biofuels are introduced: Ethanol1, Ethanol2 and Biodiesel. Following Taheripour *et al.* (2007), Ethanol1 is made of coarse-grain, Ethanol2 is made of sugarcane and Biodiesel is based on vegetable oil. Once on the market, these commodities are considered as perfect substitutes for one another and are grouped under the name Biofuels. The latter compete with petroleum products as a direct substitute.



Source: Birur, Hertel and Tyner (2008)

Figure 7: Firm's Output in Birur, Hertel and Tyner (2008)

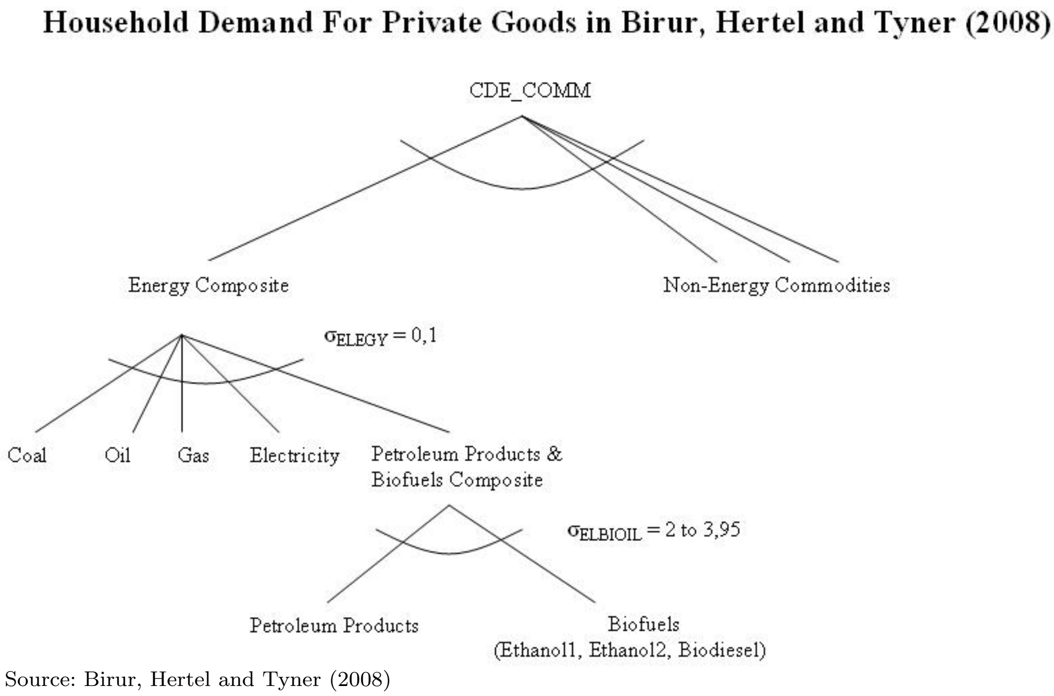


Figure 8: Household Deamand for Private Goods in Birur, Hertel and Tyner (2008)

Both the household demand for private goods (Figure 8) and the production structure (Figure 7) are modified to take this aspect into account. Petroleum products and biofuels are perfect substitutes. On the demand side, the elasticity of substitution parameter σ_{ELBIOL} between petroleum products and biofuels is generally assumed to be 2, with an exception for the US, EU and Brazil. As the elasticity of substitution between petroleum products and biofuels is of crucial importance in the model and there are not sufficient data on biomass for econometric estimation, the authors perform a calibration.

The calibration is carried out in two steps. First, the model is validated over the 2001-2006 period with an historical analysis that focuses on the main drivers of biomass consumption in the past decades: the price peak of crude oil, the replacement of MTBE by ethanol as gasoline additive in the US, the subsidies for ethanol and biodiesel in the EU and US. The key parameters of energy substitution between biofuels and petroleum products are then calibrated for the three main biofuels producing regions (EU, US and Brazil) so to replicate the actual changes that took place in the economy. It then follows that σ_{ELBIOL} has a value of 3.95 in the US, 1.65 in the EU and 1.35 in Brazil.

In this case the production function is specified so to represent the current technology employed to process fuels from biomass. As the authors state, further modifications to the model may introduce the production of biofuels by-products (following Taheripour *et al.*, 2008) and cellulosic ethanol.

Hertel *et al.* (2008) adopt the model by Birur *et al.* (2008) in order to simulate EU and US biofuel policies between between 2006 and 2015. Following the Energy Policy and Security Act of 2007, the US is expected to produce 15 billion gallons of ethanol by 2015. In the EU a conservative biofuel mandate of 6.25% by 2015 is implemented. They find that blending mandates in the US have little impact on the EU's agricultural sector (and vice versa), with the exception of oilseeds production. The EU requires large amounts of oilseeds to meet its targets and despite an increment in production by 52%, oilseeds imports surge. Their simulation also denotes a sharp reduction in exports of cereal grains, oilseeds and other food products in the EU as a consequence of increased demand for biofuel inputs.

5 The Impact of Global Biofuel Policies on Germany

The objective of this article is to assess the impact of national, European and global biofuel policies on Germany's food and land allocation. We attempt to integrate the most recent governmental mandates within a General Equilibrium Model in order to simulate the interaction of the agricultural and energy sectors in response to the envisaged expansion of the biofuel industry across the world.

Our analysis builds upon, improves and extends the results of Banse and Sorda (2009). The simulations are carried by an enhanced version of the LEITAP model as introduced by Banse *et al.* (2008b). Five scenarios simulate biofuel targets in addition to a basic benchmark implementation with no biofuel policies for comparisons. Each scenario focuses on Germany and progressively enlarges the scope of the analysis to include the EU and the rest of the world. The study also tries to capture the effects of second generation production techniques in Germany by linking ethanol production from switchgrass to the available land supply.

The simulations define equilibrium prices and quantities for food commodities, land use as well as trade flows that allow for a direct appreciation of the dynamics underlying the progressive increase in biofuel blending requirements. The findings of our model highlight a significant impact of governmental mandates. The outcome is consistent with the current literature, which anticipates changes in production and prices of agricultural commodities. In addition, the results indicate potential gains for the German agricultural sector in order to partially meet demand for biofuels feedstock from the EU.

We proceed with a description of LEITAP and then provide a detailed account of the scenarios simulated. Finally the results of the model are discussed. In the next and final section, the conclusion sums up the most important findings, highlights the weaknesses of the analysis, points out potential improvements for further areas of research and draws comparisons with the current literature.

5.1 The LEITAP Model

LEITAP is a multi-sector, multi-region, recursive dynamic CGE model derived from the GTAP framework (Hertel, 1997). The energy sector is modelled building upon the GTAP-E version by Burniaux and Truong (2002). In the latter, energy substitution is introduced into the production function by allowing energy and capital to be either substitutes or complements. Energy and capital inputs are modelled as an aggregate "capital-energy" composite. The energy related inputs are further subdivided in a tree-structure that differentiates between electricity, coal and the non-coal sector. The non-coal sector includes gas, oil and petroleum products (See Figure 9).

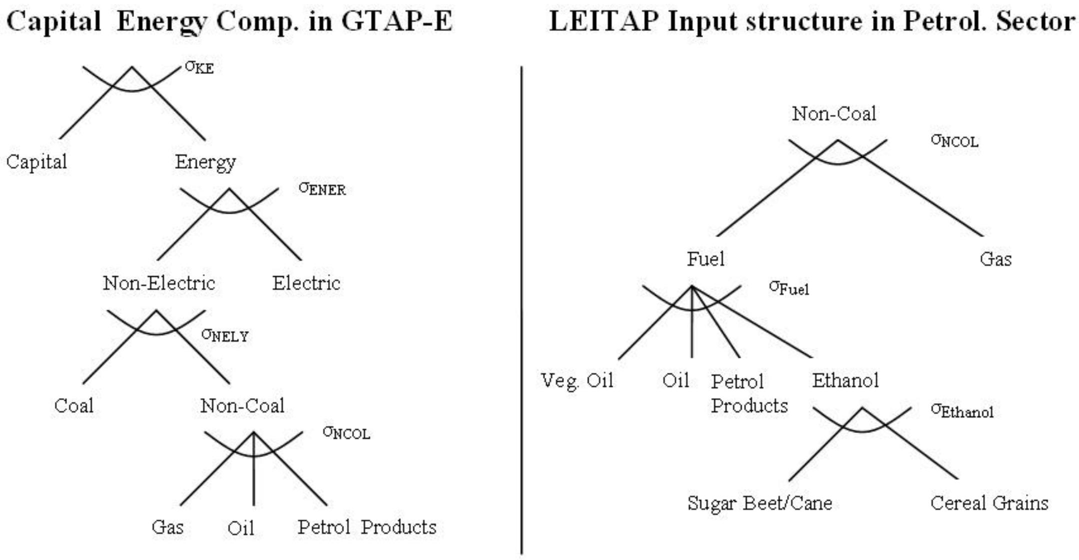
LEITAP builds on and alters the GTAP-E energy structure to model biofuel consumption. The Non-Coal inputs in the capital energy composite are subdivided as Gas and Fuel. Fuel is composed of Vegetable Oil, Oil, Petroleum Products and Ethanol. Ethanol is then derived from Sugar Cane, Sugar Beet and Cereal Grains[106]. Demand for the agricultural crops employed in first generation biofuel production is therefore directly linked to the fuel sector. In the current version of LEITAP this subdivision applies to the production structure of all commodities. However, in non-energy sectors biofuels never become important intermediate inputs and maintain low or nihil values, thus reflecting a production structure almost identical to that of GTAP-E. In the petroleum sector, on the other hand, LEITAP's modeling of biofuels plays a key role.

In the energy sector the industry's demand of intermediates strongly depends on the cross-price relation of fossil- and biofuel-energy. The output prices of the petrol industry are, among other things, a function of fossil energy and bio-energy prices. The nested CES structure implies that the relative price of crude oil with respect to agricultural prices are crucial variables of the demand for biofuels. The initial share of biofuels in the production of fuel is also important. A higher share implies a lower elasticity and a larger impact on the oil markets. Finally, the values of the various substitution elasticities (σ_{Fuel} and $\sigma_{Ethanol}$) are crucial. They represent the degree of substitutability between crude oil and biofuel crops. The estimates of the elasticity of substitution are taken from Birur *et al.* (2007) and are based on a historical simulation of the period 2001 to 2006. They correspond to a value of 3.0 for the US, 2.75 for the EU, and 1.0 for Brazil.

Land modelling is also tackled through an approach alternative to the AEZ framework adopted by Birur *et al.* (2008). Instead of the soil characterization associated with temperature and specific moisture regimes instrumental in GTAP-AEZ, LEITAP focuses on the constraints associated with changing soil-use regimes. Following Huang *et al.* (2004), different land types are matched to varying degrees of substitutability. A three-tiers structure is proposed. At the upper level, wheat, cereal grains and oil seeds all enjoy the same elasticity of substitution. Their aggregate, called "Cereal, Oilseed and Protein Cropland" (COP) has in turn the same substitutability with land for pasture and other field crops in the middle tier. The middle group, called "Field Crops and Pastures" (FCP), has a constant degree of substitutability with land for rice and "miscellaneous agricultural land" (misc) at the bottom level. See figure 10. It is generally assumed that $\sigma_3 > \sigma_2 > \sigma_1$. The nested structure implies that it is easier to transform land used for wheat into land for corn than to move from wheat to pasture.

Land supply is linked to rental prices and conversion rates. The model is calibrated such that a higher demand for agricultural space leads to the transformation of soil into cultivable land with low increment in prices as long as enough land is available.

[106] In the GTAP Database, Sugar Cane and Sugar Beet correspond to one commodity (code C_B). The category Cereal Grains (code GRO), sometimes referred to as Other Grains, includes maize (corn), barley, rye, and oats.



Source: Banse, van Meijl, Tabeau and Woltjer (2008)

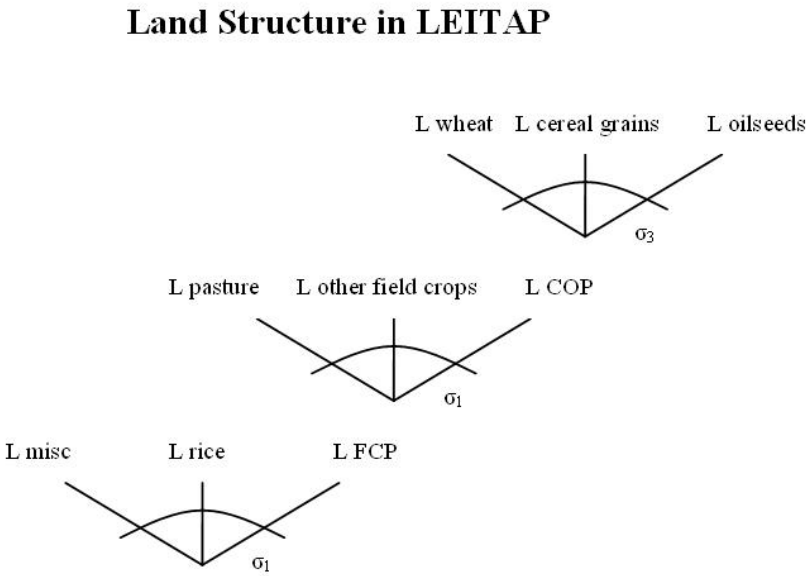
Figure 9: Capital Energy Composite in GTAP-E and Input Structure in LEITAP's Petroleum Sector

Rental rates will rise whenever almost all of agricultural land is already in use. In addition, labour and capital factor markets are segmented between agricultural and non-agricultural sectors[107].

Prices for outputs of the petroleum industry depend on any subsidies/tax exemptions affecting the price ratio between fossil energy and bio-energy. The level of demand for biofuels is determined by an enforcement of national targets through mandatory inclusion rates and the provision of input subsidies to the petrol industries.

In this paper governmental policies are modeled as blending obligations fixing the share of biofuels in transport fuel. The implementation of mandatory blending is budget neutral from a government point of view. Two key modifications were apported to the underlying framework. Firstly, the biofuel share of transport fuel is set exogenously. The model then calculates and implements a subsidy on biofuel inputs in order to achieve the given target. The input subsidy is needed to change the relative price ratio between biofuels inputs and crude oil in case the share obtained by the model is lower than the blending requirements. Secondly, "budget-neutrality" is achieved by financing the subsidy with an end user tax on petrol consumption. The end user tax on petrol endogenously generates

[107]This move intends to reproduce differences recurring in agriculture compared to other markets, such as wage differentials and returns to assets invested



Source: Banse, van Meijl, Tabeau and Woltjer (2008)

Figure 10: LEITAP Land Structure

a budget sufficient to fund the necessary subsidy on biofuel inputs. Due to the end user tax, consumers pay for the mandatory blending as end user prices of blended petrol increase. The higher price results from the use of more expensive biofuel inputs relative to crude oil in the production of fuel.

The simulations use version 6 of the GTAP database. The latter contains detailed bilateral trade, transport and protection data characterizing economic linkages among regions. All monetary values of the data are in USD millions and 2001 is used as the base year. The social accounting data originally comprising of 57 industries and 88 regions were aggregated into 23 sectors and 37 regions. The commodity aggregation specified agricultural crops that can be used for producing biofuels (e.g. cereal grains, oilseeds, sugar cane and sugar beet), sector and goods important from a land-use perspective (paddy rice, wheat, vegetable and fruits, other crops, cattle, etc.) and energy industries related to the demand for biofuels (e.g. crude oil, petroleum, gas, coal and electricity). The regional aggregation separates Germany from the remaining EU26 countries[108]. The most important economic areas outside the EU are also included and comprise Brazil, NAFTA, South Africa, Japan-South Korea, East Asia, the Rest of Asia and a composite Rest of the World area. The time path of the scenario spans from 2001 to 2020 and includes the EU enlargement from 2001 to 2007. All relevant macro-economic changes (e.g. GDP, population and factor productivity growth) between 2001 and 2007

[108] Apart from the Baltic states, Bulgaria and Romania, all EU member states are modeled as individual nations in LEITAP.

are implemented in the scenario. The results presented here always refer to the year 2007 as the starting point of the “projection period”.

Due to the extremely rapid changes in the biofuel sector, the GTAP database has been updated to include recent developments. The calibration of the use of biofuel crops in the model is based mainly on sources published in F.O. Licht (2007). The input demand for grain, sugar, and oilseeds in the petroleum industry has been adapted in order to implement first generation biofuels. Under the adjustment process, the total intermediate use of these agricultural products at the national level has been kept constant while the input use in non-petroleum sectors has been corrected via an endogenous procedure so to reproduce 2004 biofuels shares in the petroleum sector (based on their energy contents).

5.2 Description of the Scenarios

The first simulation (*GerAlone*) focuses only on Germany. The latest biofuel targets set by the German government are introduced into the model (see Section 3.1). In 2010 a biofuel quota of 5.25% is implemented as mandatory. In the 2010-2013 period the share of renewable fuel rises to 6.25%. In 2020 Germany is finally expected to comply with the European envisaged tally of 10%.

In the second scenario (*EU27*) the EU biofuel goals of the EU region are also implemented in the model. Germany’s targets remain those of the *GerAlone* simulation, while the European Union’s remaining 26 countries are aggregated into a single region (called EU26). The EU26 area is expected to meet a 3.50% blending share over the 2007-2010 period and progressively increase its quota to 6.25% in 2013 and 10% by 2020.

The 2003 EU Directive 2003/30/EC[109] set a 5.75% target of market penetration by 2010. Each country was asked to aim at an indicative 2% share by 2005. However, in 2005 biofuels accounted for only 1% of transport fuels. Similarly the 2010 goal is likely to be missed, with an expected share of 4.2%[110]. Given that a significant fraction of the EU’s biofuels are consumed in Germany, we calculated that the remaining EU countries will be able to achieve only a 3.5% blending ratio by 2010. From this point onwards a constant increment in biofuel consumption is implemented so reach a 10% share by 2020.

The next two scenarios (*Ger2ndLow* and *Ger2ndHigh*) also simulate the impact of the current biofuel objectives in Germany and the EU. However, they assess the implications of achieving a considerable fraction of renewable fuels via second generation production techniques. We assume that in Germany in 2020 3% of total fuel consumption will be met through ethanol derived from switchgrass. The EU targets remain unaltered. Switchgrass

[109] Directive 2003/30/EC of the European Parliament and of the Council on the promotion of the use of biofuels or other renewable fuels for transport, 8.5.2003.

[110] Data disclosed in the ”Proposal for a Directive of the European Parliament and of the Council on the promotion of the use of energy from renewable sources” [COM(2008) 30 final], 23.1.2008.

is not modeled as a commodity in the GTAP database and it cannot be included in the framework via aggregation of alternative commodities as it is the case with ethanol[111]. We therefore tackle this problem in two steps. First, the exogenous blending share of biofuel is set at 7% in 2020. Second, we reduce the land supply available in Germany. The reduction in land supply corresponds to the cultivated area that would be required to manufacture enough ethanol to meet the remaining 3% of the biofuel target. The production of cellulosic ethanol is under great technological change and future estimates of ethanol output per hectare of land may vary considerably. In order to account for the potential deviation in output per hectare under alternative assumptions of technical improvements, the last two scenarios specify a low- (*Ger2ndLow*) and a high-conversion efficiency (*Ger2ndHigh*) specification.

Low conversion efficiency implies that a larger portion of cultivated land has to be dedicated to ethanol production in order to meet the required 3% target from second generation bio-crops. It follows that in the low conversion scenario German land supply experiences a greater reduction in comparison to the high conversion case. The values and productivity ratios employed to determine the area of land subtracted from the original supply are included in Appendix A. One last point is important to mention. It is expected that part of the area destined for switchgrass cultivations comes from waste- and secondary soils, so that only 80% of the total surface required for cellulosic ethanol production is actually subtracted from the original land supply. Bio-crops such as switchgrass are perennial grasses with less demanding soil quality requirements in comparison to food-crops, thus partially reducing direct competition for cultivable surfaces.

The last scenario (*Global*)considers the main biofuel policies across the globe. A simulation of the simultaneous interaction of the envisaged biofuel targets in the EU and five world regions is carried out. We consider the following group of countries: Brazil, NAFTA (US, Canada, Mexico), South Africa, Japan and South Korea (as one region), East Asia (China, Hong Kong, Macau, Mongolia, North Korea), and Rest of Asia (India, Indonesia, Malaysia, Philippines, Singapore, Thailand, Vietnam, Rest of South East Asia, Bangladesh, Sri Lanka, Rest of South Asia). For each region we estimate the future biofuel share based on approximations of the energy content of projected biodiesel and bioethanol production as a share of the energy required in the transport sector. Individual government plans and mandates are taken as the basic reference for the estimates. In some cases, however, we decided to implement lower biofuel integration targets than the ones indicated by individual governments as the latter appear to be overambitious or unfeasible. A detailed description of how the individual biofuel shares have been calculated is provided in Appendix B. Table 5 shows the renewable fuels ratios assigned to each region.

[111]Ethanol is produced from sugar beet, sugar cane and corn, so that an aggregation of these commodities represents a reasonable approximation. Switchgrass cannot be replaced in a similar way.

Scenario Name	Country/Region	2007-2010	2010-2013	2013-2020
NoBFD	All Countries/Regions	No mandatory biofuel blending		
GerAlone	Germany	5.25%	6.25%	10%
EU-27	Germany	5.25%	6.25%	10%
	EU26	3.50%	5.75%	10%
Ger2ndLow	Germany	5.25%	6.25%	7%
	Land Displacement	0	0	972kHa
	EU 26	3.50%	5.75%	10%
Ger2ndHigh	Germany	5.25%	6.25%	7%
	Land Displacement	0	0	648kHa
	EU 26	3.50%	5.75%	10%
Global	Germany	5.25%	6.25%	10%
	EU26	3.50%	5.75%	10%
	Brazil	25%	25%	25%
	NAFTA	3.14%	3.86%	4.69%
	Land Displacement	94kHA	937kHa	9836kHa
	East Asia	0.75%	1%	2.5%
	Rest of Asia	1%	3%	5%
	Japan-South Korea	0%	1%	2%
	South Africa	0%	2%	2%

Source: Own Calculations

Table 5: Biofuel Scenarios

In the last simulation Germany does not employ second generation techniques to produce biofuels. However, in the US the Energy Policy Act of 2005 and the Energy Independence and Security Act of 2007 specifically target quotas of biofuel output to be derived from second generation technologies. This in turn affects NAFTA and requires estimates of second generation biofuel crop inputs. As it was the case for Germany, we calculate the amount of land necessary to include cellulosic-ethanol from switchgrrass in the model. However, for the US we estimate an average level of conversion efficiency that lies between the high and low options assumed in the *Ger2ndLow* and *Ger2ndHigh* scenarios.

Apart from integrating alternative biofuel strategies, all scenarios follow the structural policy changes that are implemented in the reference scenario *NoBFD*. They include the EU CAP Health Check (phasing out milk quotas, decoupling of remaining coupled payments, modulation of direct payments and transfers to 2^{nd} Pillar) and - between 2013 and 2020 - the multi-lateral implementation of a WTO agreement according to the Falconer Proposal of December 2008[112].

[112]The Falconer Proposal foresees a cut in developed countries' import tariffs between 50 and 70% depending on their current inbound rate. Import tariffs in developing countries will decline between 33 and 47% conditional on the existing charges

5.3 Results

Production, price levels, trade and land use of relevant agricultural commodities are presented and discussed individually. Despite the global dimension of LEITAP, we focus our analysis on the results for Germany. However, the impact of biofuel mandates on the rest of the EU and the world is also examined.

5.3.1 Production

The introduction of blending requirements leads to a significant increase in the production of arable crops in Germany. In 2020 the output of arable crops will be 9.6% to 15.4% higher than in 2007 (see Table 6). Such changes are particularly relevant given that under the no-biofuels reference scenario the increment in supply would remain below 2% in the 2007-2020 period and even decrease by -0.32% between 2013 and 2020 due to trade liberalisations.

The role of Germany in the EU is a key component in the evolution of Germany's agricultural sector. If biofuel mandates are implemented across all EU member states(*EU27* scenario), German domestic production will increase the aggregate supply of arable crops from 9.6% to above 14%. The inclusion of global policies (*Global* scenario) has little effects. German agriculture is mostly affected by its own domestic targets and the EU biofuel goals, while the implementation of blending mandates in the rest of the world plays only a minor role. On the other hand, the ability to produce 3% of the mandated quotas from second generation techniques (*Ger2ndHigh* and *Ger2ndLow*) reduces the actual output change in arable commodities and decreases the impact of the EU mandate on German agricultural production. This partially indicates that second generation technoloies, as modelled here, would curb demand for arable products.

The same trends emerge for biofuel crops (the crops employed in the production of ethanol or biodiesel), though the magnitude of change is greater. Coarse grains and oilseeds highlight a clear case where biofuel policies significantly push for substantially higher production levels. While in the reference case the output of coarse grains in Germany is expected to decrease by 2.7% between 2007 and 2020, the implementation of biofuel shares reverts this tendency and grains output increases between 6% and 24.4% across the various scenarios. The magnitude of the change is even greater among oilseeds production in Germany. The latter jumps from an increment of 47% between 2007 and 2020 in the *NoBFD* case to a staggering 102.4% when bioethanol and biodiesel policies across the globe are modelled. The simulation results also indicate that a similar response occurs within the EU26 aggregate once the remaining European countries implement their respective targets.

In Germany the output of agricultural commodities competing with biofuel crops for land is hardly affected by blending obligations and little production variations are registered in the model's simulations between 2007 and 2020. The supply of wheat is the

	Germany			EU26		
Scenario	**2007-13**	**2013-20**	**2007-20**	**2007-13**	**2013-20**	**2007-20**
		Arable Crops			**Arable Crops**	
NoBFD	2.0	-0.3	1.7	1.4	-1.4	0.0
GerAlone	6.5	3.0	9.6	1.5	-1.3	0.2
EU27	9.2	4.9	14.5	4.8	2.2	7.2
Ger2ndHigh	9.2	1.4	10.7	4.8	2.2	7.2
Ger2ndLow	9.2	0.4	9.6	4.8	2.2	7.2
Global	9.9	5.1	15.4	5.1	2.4	7.6
		Biofuel Crops			**Biofuel Crops**	
NoBFD	2.9	2.6	5.6	-0.1	0.4	0.2
GerAlone	10.5	8.8	20.2	0.2	0.7	0.9
EU27	13.8	11.3	26.7	11.7	12.0	25.0
Ger2ndHigh	13.8	7.0	21.8	11.7	11.8	24.8
Ger2ndLow	13.8	6.2	20.9	11.7	11.8	24.9
Global	14.5	11.6	27.8	12.3	12.3	26.1
		Cereal Grains			**Cereal Grains**	
NoBFD	1.2	-3.9	-2.7	1.7	-1.3	0.3
GerAlone	4.6	1.4	6.0	1.7	-1.3	0.4
EU27	11.1	10.4	22.6	12.9	10.3	24.5
Ger2ndHigh	11.1	6.3	18.1	12.9	10.2	24.4
Ger2ndLow	11.1	5.4	17.0	12.9	10.2	24.5
Global	12.0	11.1	24.4	13.5	10.6	25.5
		Oilseeds			**Oilseeds**	
NoBFD	17.6	24.6	46.5	6.3	10.6	17.5
GerAlone	47.2	32.1	94.5	7.9	11.8	20.6
EU27	53.9	29.5	99.2	38.9	28.7	78.7
Ger2ndHigh	53.9	17.0	80.0	38.9	28.2	78.1
Ger2ndLow	53.9	14.5	76.3	38.9	28.2	78.1
Global	56.1	29.5	102.1	41.1	29.3	82.4

Source: Own Results from LEITAP

Table 6: Change in Agricultural Production (in %) in Germany and the EU26

only exception and is projected to decrease in volume between 3% to 5% with respect to the reference scenario.

5.3.2 Prices

The increased demand for biofuel crops has a direct impact on world and domestic prices. Under the reference scenario (*NoBFD*) the intensity of agricultural production decreases due to a cut in price and income support (EU Health Check and WTO agreement). This development leads to a general decline in prices for agricultural commodities in

	Germany			World		
Scenario	**2007-13**	**2013-20**	**2007-20**	**2007-13**	**2013-20**	**2007-20**
	Prim. Agric. Products			**Prim. Agric. Products**		
GerAlone	0.90	1.21	1.81	0.11	0.07	0.17
EU27	2.11	2.97	4.14	1.12	1.23	1.79
Ger2ndHigh	2.11	1.97	3.21	1.12	1.10	1.67
Ger2ndLow	2.11	2.12	3.36	1.12	1.12	1.68
Global	2.53	3.13	4.52	1.96	2.07	2.75
	Cereal Grains			**Cereal Grains**		
GerAlone	1.47	2.80	3.71	0.07	0.09	0.16
EU27	3.86	7.90	9.79	1.69	2.79	3.52
Ger2ndHigh	3.86	7.18	9.10	1.69	2.74	3.48
Ger2ndLow	3.86	8.13	10.0	1.69	2.74	3.48
Global	4.43	8.36	10.5	3.17	4.55	5.77
	Oilseeds			**Oilseeds**		
GerAlone	5.68	9.03	12.6	0.26	0.31	0.50
EU27	9.01	16.6	21.7	2.01	2.65	3.66
Ger2ndHigh	9.01	12.6	17.8	2.01	2.39	3.41
Ger2ndLow	9.01	13.9	19.2	2.01	2.43	3.46
Global	10.3	18.1	23.9	4.51	7.54	8.24
	Wheat			**Wheat**		
GerAlone	0.53	1.01	1.36	0.05	0.04	0.09
EU27	1.62	2.52	3.43	0.85	0.83	1.32
Ger2ndHigh	1.62	2.48	3.39	0.85	0.79	1.28
Ger2ndLow	1.62	2.84	3.73	0.85	0.81	1.30
Global	2.04	2.54	3.67	1.44	1.34	1.93

Source: Own Results from LEITAP

Table 7: Change in German Domestic Prices and World Prices (in %) Relative to the Reference Scenario.

Germany, the EU and the world. The introduction of blending mandates pushes the demand for biofuel inputs and indirectly decreases the supply of other crops through land reallocation. The effect is an upward shift in prices in comparison to the original framework. The percentage price changes relative to the underlying *NoBFD* scenario are given in Table 7.

World prices are calculated as a trade-weighted average of export prices. Domestic market prices refer to producer prices and are a result of world and domestic market developments. In general, world prices become increasingly important for domestic markets that are more integrated into the international trade. Consequently, the largest impact on both domestic and international prices occurs in the *Global* scenario where German, European and world biofuel mandates are modelled simultaneously.

Relative to the standard case, the price of cereal grains in Germany increases by around 10% between 2007 and 2020 once domestic and international mandates are taken into account. Oilseeds experience an even more dramatic rise and surge by more than 20% if EU and global biofuel policies are modelled[113]. In Germany primary agricultural commodities[114] witness a 4.52% rise in domestic prices over the 2007-2020 period. Due to the reallocation of land and a decrease of wheat production following the introduction of global biofuel mandates[115], the model also simulates a 3.67% increase in wheat prices between 2007 and 2020 in relation to the reference scenario. Other agricultural commodities indirectly competiting for land with biofuel crops (paddy rice, cattle, other crops) experience smaller but similar trends. In general German agricultural commodities other than biofuel crops experience a small but visible inflation. In the remaining EU26 countries the impact of blending mandates has a similar effect.

The percentage change of world prices in the *Global* scenario over the 2007-2020 interval also display a significant increment in relation to the base case. The price of cereal grains rises by more than 5% while oilseeds, sugar cane and sugar beet increase by over 8%. The aggregation of primary agricultural products presents a more modest price increment at around 3%. Other agricultural sectors (i.e. cattle, wheat, paddy rice) competing with biofuel crops for land experience minor price alterations (around 1% or less) over the 2007-2020 period in relation to the reference scenario.

Changes to the pricing patterns of agricultural products associated with the implementation of blending mandates across the world are affected by the underlying liberalization assumptions implemented in the model. International trade is influenced by a surging demand for biofuel crops, which is partially met by increased domestic production. The consequent reallocation of land (see Section 5.3.4) affects the supply of competing commodities, though the effects on their prices are reduced by trade liberalization and a reduction in farmer's support in the EU. The result is a significant increase in prices for biofuel crops in Germany and a smaller but still relevant increment at world level with respect to the base case.

5.3.3 Trade

Imports and exports are assessed via percentage changes in volume valued at world market prices (see Table 8 and Table 9). The exports of coarse grains in Germany are expected to decrease by -12.5% between 2007 and 2020 in the basic scenario. If Germany

[113]Notably, sugar cane and sugar beet witness a tremendous upsurge in domestic prices. However, the latter have low production levels in in Germany that do not vary over the 2007-2020 period. The rise in domestic prices is explained by the substantial increase in imports driven by biofuel mandates.

[114]This group includes cereal grains, oilseeds, cattle, paddy rice, sugar cane and sugar beet, wheat, milk, horticulture. The aggregation is wheighted with respect to the relative production level of each crop.

[115]Wheat directly competes with cereal grains and oilseeds for land (see LEITAP land structure in Section 5.1).

	Germany			EU26		
Scenario	**2007-10**	**2013-20**	**2007-20**	**2007-13**	**2013-20**	**2007-20**
	Cereal Grain Exports			**Cereal Grain Exports**		
NoBFD	7.4	-18.5	-12.5	4.7	-27.5	-24.1
GerAlone	3.7	-24.3	-21.5	5.1	-26.7	-23.0
EU27	28.7	12.8	45.2	-6.6	-38.7	-42.7
Ger2ndHigh	28.7	14.1	46.9	-6.6	-38.7	-42.8
Ger2ndLow	28.7	11.5	43.6	-6.6	-38.6	-42.6
Global	30.9	12.8	47.6	-3.0	-38.4	-40.3
	Oilseed Exports			**Oilseed Exports**		
NoBFD	11.0	21.0	34.4	11.5	24.6	38.9
GerAlone	-14.0	-18.5	-29.9	31.9	39.6	84.1
EU27	27.8	8.4	38.6	-9.6	-11.6	-20.1
Ger2ndHigh	27.8	27.7	63.3	-9.6	-21.2	-28.7
Ger2ndLow	27.8	20.2	53.7	-9.6	-20.9	-28.5
Global	35.7	8.8	47.5	-4.1	-8.6	-12.4
	Sugar Exports			**Sugar Exports**		
NoBFD	23.0	62.7	83.8	121.2	29.4	210.7
GerAlone	-17.9	32.3	1.6	124.4	34.0	222.4
EU27	-20.5	0.1	-22.8	15.0	-2.1	43.0
Ger2ndHigh	-20.5	51.3	16.7	15.0	-4.3	39.7
Ger2ndLow	-20.5	46.6	13.1	15.0	-4.2	39.9
Global	-24.3	-5.4	-28.9	15.0	-1.1	42.8

Source: Own Results from LEITAP

Table 8: Change in Volume of Exports (in %) in Germany and the EU26

were to introduce biofuel mandates, exports would further decline by -21.5%. Once the blending mandates are extended to the rest of the EU and the world, exports radically invert the above trend and increase by more than 45% in the 2007-2020 period. On the other hand, the change in coarse grains imports in Germany display a relatively stable outcome across the alternative scenarios.

The combined results of imports and exports suggest that Germany will respond to the biofuel mandates by increasing domestic production and reducing exports, rather than by increasing imports from abroad. Exports rise in response to increased demand from the EU, which is partially met by higher German production. Hence, with respect to the balance of trade for coarse grains, Germany benefits from a successful implementation of the biofuel directive among European countries, while the remaining EU26 members witness a worsening of the terms of trade due to a decline in exports and a significant rise in imports.

	Germany			EU26		
Scenario	**2007-13**	**2013-20**	**2007-20**	**2007-13**	**2013-20**	**2007-20**
	Cereal Grain Imports			**Cereal Grain Imports**		
NoBFD	-0.7	-3.0	-3.8	7.3	19.8	28.6
GerAlone	1.0	0.4	1.4	6.7	18.6	26.5
EU27	-0.7	-0.3	-1.0	60.6	87.5	201.1
Ger2ndHigh	-0.7	-1.3	-2.0	60.6	87.4	200.9
Ger2ndLow	-0.7	-0.5	-1.1	60.6	86.8	200.0
Global	-0.9	-0.3	-1.2	60.1	88.1	201.1
	Oilseeds Imports			**Oilseeds Imports**		
NoBFD	14.1	16.5	32.9	5.5	2.9	8.5
GerAlone	56.1	46.4	128.6	5.4	2.6	8.1
EU27	57.5	51.4	138.4	71.7	56.2	168.1
Ger2ndHigh	57.5	26.2	98.7	71.7	56.0	167.7
Ger2ndLow	57.5	27.3	100.4	71.7	56.0	167.8
Global	55.6	50.6	134.2	67.9	54.9	160.1
	Sugar Imports			**Sugar Imports**		
NoBFD	-44.8	3.0	-43.0	-27.5	657.3	232.2
GerAlone	1.7	57.4	53.0	-32.7	748.1	227.7
EU27	36.4	139.4	166.1	41	1212.1	689.3
Ger2ndHigh	36.4	49.4	66.0	41.0	1192	677.3
Ger2ndLow	36.4	55.4	72.6	41.0	1195.7	679.5
Global	46.8	154.2	195.2	46.2	1241.1	724.2

Source: Own Results from LEITAP

Table 9: Change in Volume of Imports (in %) in Germany and the EU26

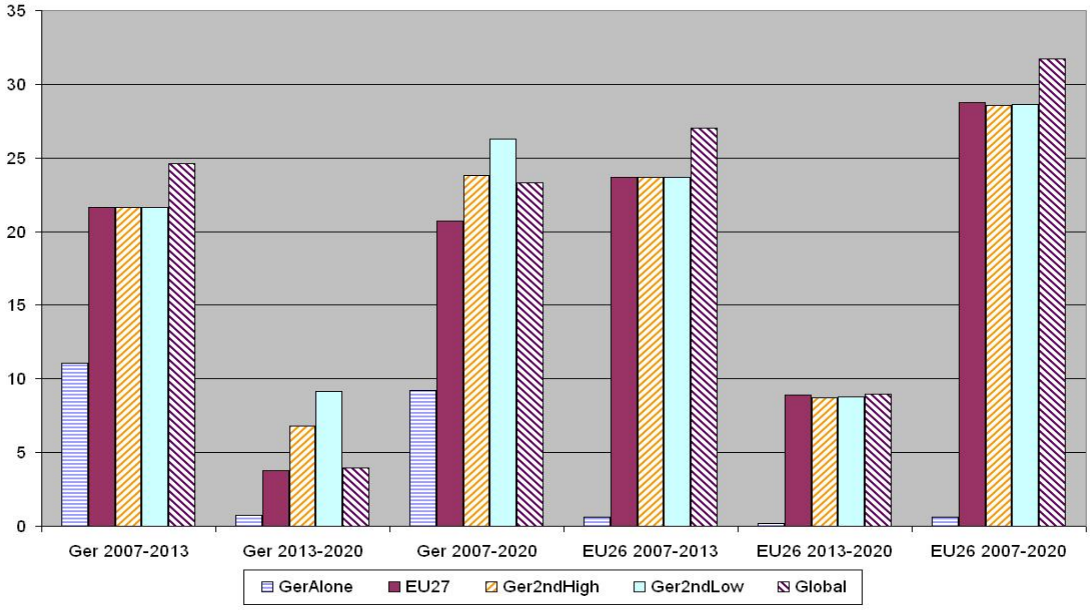
Oilseeds' trade dynamics change significantly with the introduction of biofuel quotas. In Germany, under the no-biofuels scenario, both imports and exports are expected to increase by more than 30% between 2007 and 2020. If only Germany were to successfully implement its blending targets, exports would drop by -29.9% and imports would surge by 128% over the same period. Once the impact of biofuel policies in the rest of Europe and the world are taken into account, oilseeds exports increase again and fluctuate between 38.6% and 63.3% (depending on the scenario), while imports maintain a similar increment shown in the *GerAlone* case. The model therefore projects an ambiguous effect on the German balance of trade for oilseeds. The increase in oilseeds production is not sufficient to meet internal demand and imports consequently rise, coupled by the fact that domestic prices experience a steeper upsurge compared to international market prices.

The model further simulates a boost in sugar imports into Germany, while exports dramatically fall. From a -43% reduction in imported sugar between 2007 and 2020 in the reference case, the introduction of biofuel quotas progressively leads to an expansion of 195% over the 2007-2020 period in the *Global* scenario. Domestic exports drop from an initial positive growth of 83.8% to a decline of more than 20%.

Within the remaining EU countries, biofuel policies clearly lead to a substantial deterioration in the trade balance of agricultural commodities affected by biofuel production. EU26 members unilaterally decrease exports and increase imports for arable and especially biofuel crops between 2007 and 2020 once blending mandates are introduced.

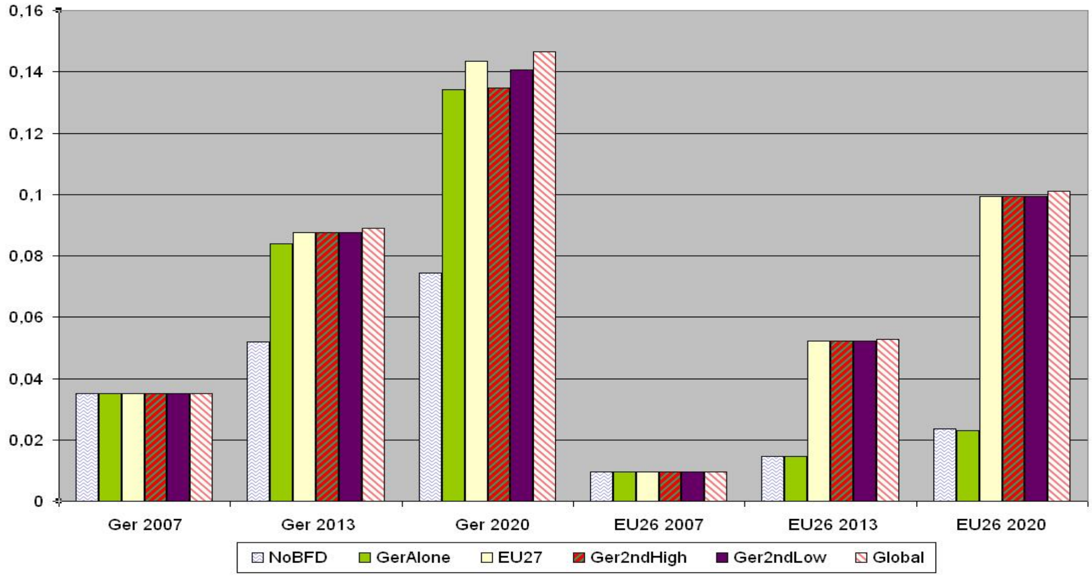
5.3.4 Land Use

The implementation of blending mandates has a direct impact on land allocation and prices. The inclusion of the EU Health Check and WTO agreement in the model leads to a general decline in the cost of cultivable land in Germany and the EU. Biofuel policies increase the demand for agricultural commodities and hence drive land prices upwards. Figure 11 displays the change in land prices relative to the *NoBFD* reference scenario. Between 2007 and 2020, in Germany the cost of cultivable surface rises between 9% to well above 20% of the no-biofuel case. Among the remaining EU countries, over the same period the change of land prices relative the reference scenario is higher than the 28%. The stronger price reaction in the EU-26 indicates a tighter land market. In absolute terms, the change in land prices in Germany remains negative due to the above mentioned trade liberalizations. However, blending mandates considerably reduce the decrease implicit in the model. As one may expect, biofuel policies have a positive impact on the cost of land (or as it is the case here, they curb its decline).



Source: Own Results from LEITAP

Figure 11: Change in Land Price (in %) Relative to the Reference Scenario *NoBFD*



Source: Own Results from LEITAP

Figure 12: Share of Agricultural Land Used for Biofuel Crops in Germany and the EU

It is relevant to mention the impact of second generation production techniques in the *Ger2ndLow* and *Ger2ndHigh* scenarios. The latter are modelled by reducing the available land supply in Germany by the amount necessary to manufacture 3% of the biofuel target via ethanol derived from switchgrass. Unsurprisingly, under this setting the percentage change of land prices is the largest (in absolute terms and relative to the reference case). However, the magnitude of the change conforms to the trend outlined in the other scenarios and may reasonably lead to the conclusion that second generation techniques may reduce demand for food crops, but will maintain a high demand for land and thus contribute to the rise in prices.

Land allocation is also altered by mandatory blending targets. Figure 12 depics the share of total agricultural land used for biofuel crops. Whereas in Germany slightly more than 3% of the total agricultural surface is devoted to commodities employed in the production of biofuels in 2007, the ratio moves to above 14% in 2020 (*Global* scenario). In the remaining states of the European Union a similar pattern emerges and farming products employed for biofuel production move from occupying less than 1% to almost 10% of the total land supply between 2007 and 2020. These results coincide with an increment in production that follows the mandatory fulfillment of the quotas set by the government. Even though an increase in the share of land devoted to biofuel crops may seem a straighfoward outcome, it is interesting to notice that its reallocation induces a substantial upward pressure on land prices. Due to the biofuel targets, a change in crop patterns and a relatively low spare capacity contribute to a redistribution of land resources and higher prices.

6 Conclusion

Our analysis focuses primarily on Germany's agricultural sector and shows that current biofuel policies may have a significant impact on agricultural and food production. According to the model's simulations, production and land allocation of the relevant crops undergo remarkable changes. Mandatory biofuel shares increase the demand for the commodities employed as intermediary inputs. The higher demand is then translated into an increase in output. Relative to the reference scenario, cereal grains and oilseeds yields grow by more than 20% and 50% respectively. The increment in domestic production is necessarily followed by a reallocation of land resources. The share of land devoted to crops employed in biofuel production expands from around 3% in 2007 to about 14% in 2020. The price of cultivable land is also affected and it rises by more than 20% between 2007 and 2020.

The evolution of imports and exports for German crops is closely connected to the implementation of biofuel policies across the remaining EU26 countries. The balance of trade of the EU26 is negatively affected by the blending targets. Despite an increase in production of the relevant inputs, in the EU26 exports of both grains and oilseeds decline while imports significantly increase in order to meet the envisaged biofuel shares. The inability to sufficiently augment the output level of the relevant commodities is matched by the EU26's less flexible reallocation of land. The EU26 region is characterized by a smaller increment in the share of land for biofuel crops and a higher growth in soil prices in comparison to Germany. In addition, part of the expansion in German production of biofuel crops is exported to the EU, leading to a less clear impact on Germany's balance of trade.

It is interesting to notice that global biofuel policies outside of Europe have little impact on Germany's agriculture. The simulations show that Germany is mostly affected by its own domestic targets as well as the EU's blending mandates, while the rest of the world's biofuel strategies do not affect German agri-food production.

The implementation of international biofuel targets has a small but evident impact on world prices of agricultural commodities. In relation to the reference scenario, arable and energy crops become more expensive. The changes in world prices range between 4.3% for arable crops to 8.2% for oilseeds. The model results are relatively conservative in comparison to the current literature. In their review of current studies on food prices projections due to biofuel polices, Gerber *et al.* reports that vegetable oil prices are expected to increase by more than 30% between 2011 and 2016. Wheat, corn and soybean prices are forecasted to rise by a lesser degree (3% to 15%).

Price changes in the German market are considerably stronger. Over the 2007-2020 period, LEITAP simulates a 10% increase for cereal grains and a 23% increment for oil seeds in comparison to the reference scenario. Sugar prices increase even by more than

50%, though the rise is caused by soaring imports. Interestingly, biofuel mandates have a small effect on the price of agricultural products competing with biofuel inputs for land. Wheat experiences the most signifcant alterations, though its price change between 2007 and 2020 is less than 4%.

Key insights of our analysis correspond to the findings presented in other publications. Firstly, the EU's agricultural sector is hardly affected by the current biofuel policies of other countries (Hertel *et al.* (2008); see section 4.2.3). Secondly, the European production and price of arable crops increases significantly. Cereal grains and especially oilseeds witness a considerable expansion (Banse and Grethe (2008) using the ESIM model; see section 4.3.1). Thirdly, the rise in production is matched by a large drop in exports and increased imports of biofuel crops (Gohin and Moschini (2007)).

By looking at Germany separately, our study allows us to identify specific dynamics that differentiate German agriculture from the rest of the EU. According to our analysis, the German farming sector partially feeds Europe's demand for biofuel feedstock. A signifcant part of its expansion in oilseed and cereal grains production is destined for the continental market. While in the EU exports of biofuel crops dramatically drop and imports increase, Germany's cereal grain exports boost by 57% in relation to the reference scenario once European blending mandates are modelled.

Germany allocates a greater portion of its land to energy crops compared to the remaining EU countries. At the same time the price of cultivable land in the EU rises more significantly. A more flexible land supply plays a significant role by allowing Germany to partially benefit from the EU biofuel mandate.

The adoption of cellulosic ethanol indicates the possibility to ease competition between the use of agricultural products for food and energy purposes. However, land allocation will be similarly affected by first and second generation manufacturing technologies.

Obviously our analysis does not avoid criticism and can be further improved. For instance, by-products of biofuel manufacture should be included in the model in order to adequately assess the implications of blending mandates on the livestock industry (see for instance Tokgoz *et al.* (2007), Taheripour *et al.* (2008) and Taheripour *et al.* (2009)).

Future versions of the GTAP database will cover biofuels as commodities in the input-output matrices, so that an evaluation of related policies may be more accurate. In addition, new research may lead to more precise estimates of the production of ethanol from switchgrass via second generation techniques. Nonetheless, LEITAP and the scenarios we modelled provide results that are in line with other studies. The change in land structure, the evolution of production and the impact on prices confirm that biofuels will alter the European farm sectors and suggest that Germany's agriculture will partially meet the demands of its neighbours.

A Switchgrass Conversion Ratios

This paper assumes 6 tonnes of switchgrass per acre as a reasonable yield. A conservative estimate of current conversion technology for second generation biofuels suggests that 1 tonne of switchgrass produces 60 gallons (US gallons) of ethanol. This gives us 360 gallons of ethanol per acre. We also consider a more efficient conversion process, such that 90 gallons of ethanol may be produced from 1 tonne of switchgrass (see Table 10).

Larson (2008b) investigates switchgrass yields in Tennessee. On East Tennesse Dandridge soil (pasture land) an average of 5.7 tonnes per acre was obtained. The more fertile West Tennessee Loring soil (crop land) averaged 9.1 tonnes per acre. Carrier and Clausen (2008) report 5 tonnes per acre as the standard yield of switchgrass by comparing alternative studies. Schmer et al. (2008) conducted experiments on 10 farms in the Northern Great Plains in the US (Nebraska, North Dakota and South Dakota) and reported annual yields of established fields averaged 2.1-4.5 tonnes of switchgrass per acre[116]. Kszos *et al.* (2002) refer to a study conducted by the Virginia Polytechnic Institute and State University (VPI) and the Auburn University (AU). Average dry switchgrass in the 1992-2001 period ranged between 3.2 and 7.6 tonnes per acre. The best crop variety averaged 6.8 tonnes per acre across all site in 2001[117].

The figures that report average switchgrass yields may vary considerably due to fertilizers use, type of crop, land and weather conditions. However, the 6-tonnes-per-acre yield adopted in this paper should be a reasonable middle value among current experimental results.

The conversion ratio of switchgrass into ethanol is another crucial factor in determining the land required for the production a given quantity of fuel. Perkis *et al.* (2008) provide two conversion estimates. A conservative figure would see 67.6 gal of ethanol per tonne of dry switchgrass, while a more optimistic quotient would assume an output of 79.0 gal per tonne[118]. Schmer (2008) on the other hand assumes a conversion rate of 100 gal of ethanol per tonne of switchgrass[119]. In our calculations we considered the two extreme cases, namely a conservative approach with 60 gal of ethanol per tonne of switchgrass and a more optimistic view with 90 gallons of ethanol per tonne.

[116] Original data was given as 5.2-11.1 Mgha-1. Data has been converted into tonnes per acre in order to be comparable with other studies.

[117] Original figures where in Mg/ha.

[118] Perkis *et al.* (2008) derive their "conservative" estimates from McLaughling et al. (1999), Spatari et al. (2005), while they take their more optimistic version from Tiffany (2007).

[119] Original value was 0.38 liters*kg-1. Schmer (2008) takes this value from the Renewable and Applicable Energy Laboratory, *Energy and Resources Group Biofuel Analysis Meta-Model* (University of California, Berkeley), (2007).

1 acre	=	0.404686	hectare	ha		
1 gallon (gal)	=	3.748544	liter	(l)		
1 liter ethanol	=	0.7894	kilogram	(kg)		
1 liter biodiesel	=	0.880	kilogram	(kg)		
1 tonne (t) ethanol	=	0.638	tonne of oil equivalent			(toe)
1 tonne (t) biodiesel	=	0.86	tonne of oil equivalent			(toe)
Switchgrass Yield	=	6	t/acre			
Low Conversion	=	60	gal/t	=	1.679441	toe/ha
High Conversion	=	90	gal/t	=	2.519162	toe/ha
Energy supply from second generation ethanol				=	2041	ktoe
Required land surface - Low Conversion Rate				=	1.215	million ha
Required land surface - High Conversion Rate				=	0.810	million ha
Actual reduction in available land due to switchgrass cultivations						
Low Conversion Case	=	0.972	million ha			
High Conversion Case	=	0.648	million ha			

Source: Various Online Resources

Table 10: Conversion Ratio for Switchgrass-Land into Ethanol

The PRIMES model estimates that in Germany energy demand for transport will be equivalent to 68.03 mToe[120]. Our model calculates that cellulosic ethanol will supply 3% of the latter, which is equivalent to 2.04 mToe. Based on the conversion rates given in Table 10, the cultivation of swithgrass for the production of cellulosic ethanol requires a surface of 1.215 million hectares (ha) under conservative conversion estimates and 0.810 million heactares for more optimistic processing technologies (Table 10).

[120]One can find this data on page 23 on the following file: *http://ec.europa.eu/environment/climat /pdf/climat_action/analysis_appendix.pdf*.

B Estimation of Global Biofuel Shares

The calculation of blending mandates outside of Germany and the EU is based upon the current biofuel policies reported in Section 3 and LEITAP's country aggregation. Here we proceed with a description of how the blending mandates for each composite region[121] are determined.

NAFTA (USA, Canada, Mexico). First we determine the energy content of Canada's and the United States' biofuel targets (Mexico has no renewable fuel policies), based on the conversion ratios in Table 10. Given NAFTA's energy demand in the transport sector and reported in the World Energy Outlook 2008, we calculate the percentage share provided by the biofuel targets[122].

The Canadian government established a blending target until 2012. We maintain this target constant until 2020. The US proposed a given production of ethanol from cellulosic sources. In order to account for second generation biofuel output, we follow a procedure similar to the one used for Germany in the *Ger2ndLow* and *Ger2ndHigh* scenarios. Namely, we calculate the energy contribution to the transport sector only for first generation production techniques, but reduce the land supply by the amount necessary to produce the required cellolusic ethanol targets (based on the data in Table 10). However, instead of using a high and low conversion ratios for ethanol output per tonne of switchgrass, we applied the average of the two boundary values.

One more consideration should be mentioned. We derive the blending levels in 2007, 2010, 2013 and 2020 by assuming a constant growth in biofuel production between the years given as reference point by the US and Canadian governments (See Table 11 and Table 12).

East Asia (China, Hong Kong, Macau, Mongolia, North Korea). This region is dominated by China's biofuel plans. Data on energy demand and fuel consumption in Macau, Mongolia and North Korea is not easily available. To avoid this problem, we approximate East Asia's biofuel intergration based on China's blending mandates. We calculate China's biofuel share of energy consumption in the transport sector and then ascribe to the East Asia region a slightly lower value.

The Medium and Long Term Plan for Renewable Energy announced by the NDRC in August 2007 established given quantities of ethanol and biodiesel to be produced by

[121]The aggregate regions were biofuel policies are implemented consist of NAFTA, East Asia, Rest of Asia

[122]The World Energy Outlook 2008 provides data on energy demand from the transport sector in 2006, 2015 and 2020. In order to determine its values in 2007, 2010, 2013 and 2030, the data is extrapolated by assuming a constant growth rate between the 2006-2015 and the 2015-2020 periods

Targets in Billion Liters				
	2007	2010	2013	2020
Canada				
Biodiesel	0	0	0.52	0.52
Ethanol	0	0	1.90	1.90
USA				
Biodiesel	0	2.44	4.40	12.45
Ethanol	17.62	44.98	51.73	56.23
Cellosic Ethanol	0	0.37	3.75	39.36
NAFTA				
Biodiesel	0	2.44	4.92	12.97
Ethanol	17.62	44.98	53.63	58.13
Cellulosic Ethanol	0	0.37	3.75	39.36
Biofuel Targets in Mtoe				
	2007	2010	2013	2020
NAFTA				
Biodiesel	0	1.85	3.73	9.81
Ethanol	8.87	22.65	27.01	29.28
Total	8.87	24.50	30.74	39.09

Source: Own Calculations

Table 11: NAFTA's Biofuel Targets

NAFTA				
	2007	2010	2013	2020
Energy in Transport Sector (Mtoe)	762	779	797	834
Biofuel Share in Transport Sector (%)	1.16	3.14	3.86	4.69
Reduction in Land Supply in kHa	0	94	937	9836

Source: Own Calculations

Table 12: NAFTA's Final Specifications

2010 and 2020[123]. We determine the energy content of the biofuel targets and extrapolate their values in 2013 by assuming a constant growth rate between 2010 and 2020. The blending mandated is calculated as the percentage of energy demand in the Chinese transport sector supplied by the biofuel targets[124] (Table 13).

Rest of Asia (Indonesia, Malaysia, Philippines, Singapore, Thailand, Vietnam, Rest of South East Asia, Bangladesh, India, Sri Lanka, Rest of South Asia). In the Rest of Asia region the following countries have set biofuel targets: India,

[123]In the original plan these quantities are expressed as in million tonnes

[124]Refer again to Table 10 and the World Energy Outlook 2008 for the conversion ratios and the estimates of the energy demand in the transport sector respectively

China			
	2010	2013	2020
Official Ethanol Target (MTonnes)	2	n.a.	10
Official Biodiesel Target (MTonnes)	0.2	n.a.	2
Energy from Biofuels (Mtoe)	1.45	2.41	8.1
Energy in Transport Sector (Mtoe)	175.7	216.6	310
Biofuel Share in Transp. Sector (%)	0.82	1.11	2.61
East Asia			
	2010	2013	2020
Biofuel Share in East Asia (%)	0.75	1	2.5

Source: Own Calculations

Table 13: East Asia and China's Biofuel Shares

Indonesia, Malaysia and Thailand. However, we did not implement the targets set by the respective governments in a procedure similar to the one applied for the NAFTA and East Asia regions.

India legislated an overall renewable fuels blending target of 20% by 2017. Similarly, Indonesia mandated a share of 20% for biodiesel and 15% for ethanol by 2025. The implementation of such objectives seems unrealistic. We do not adopt official government targets to estimate the region's biofuel blending ratios.

Under the assumption that the Rest of Asia region has the resources to contribute significantly to the production of biofuels and that several political initiatives aim at implementing ambitious blending programs, it seems reasonable to model an integration share of 1% by 2010, 3% by 2013 and 5% by 2020.

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